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CONTENTS

PAGES

Lime-secreting algae from the Pennsylvanian and Permian of Kansas. By J. Harlan Johnson 1087–1120

Geology of the Los Pinos Mountains, New Mexico. By J. T. Stark and E. C. Dapples 1121–1172

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PAPERS IN PRESS FOR FORTHCOMING ISSUES

KOOLAU BASALT SERIES, OAHU, HAWAII. By C. K. Wentworth and Horace Winchell

HONOLULU SERIES, OAHU, HAWAII. By Horace Winchell

TOPOGRAPHY OF THE GULF OF MAINE—FIELD SEASON OF 1940. By Harold W. Murray

SOLUTION SCULPTURING IN LIMESTONE PEBBLES. By H. W. Scott

STRATIGRAPHY OF THE UPPER CAMBRIAN, LLANO UPLIFT, TEXAS. By Josiah Bridge, V. E. Barnes, and P. E. Cloud, Jr.

FAULT PROBLEMS IN FAULT PLANES. By R. H. Beckwith

ZION NATIONAL MONUMENT, UTAH. By Herbert E. Gregory and Norman C. Williams

DEVONIAN ROCKS OF CENTRAL TEXAS. By V. E. Barnes, Preston E. Cloud, Jr., and L. E. Warren

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LIME-SECRETING ALGAE FROM THE PENNSYLVANIAN AND PERMIAN OF KANSAS

BY J. HARLAN JOHNSON

CONTENTS

	Page
Abstract	1087
Introduction and acknowledgments	1088
Geographical distribution	1088
Stratigraphy	1088
Limestones	1089
General	1089
Algae	1089
Classification	1089
Systematic descriptions	1094
Algal threads	1107
Perforating algae	1107
Algal deposits	1107
General statement	1107
Ecology	1108
Relation of algal deposits to cyclothems	1108
References	1108

ILLUSTRATIONS

Figure	Page
1. Map of Kansas, showing areas where the limestones were obtained	1089
2. Generalized section of Lower Permian rocks of Kansas	1090
3. Generalized section of upper Pennsylvanian rocks in Kansas and Nebraska	1091
4. Generalized section of middle Pennsylvanian rocks in Kansas and Nebraska	1092
5. Generalized section of Lower Pennsylvanian rocks of Kansas and Nebraska	1093

Plate	Facing page
1. *Epimastopora*	1110
2. *Epimastopora* and *Anchicodium*	1111
3. *Anchicodium* and *Girvanella*	1112
4. *Girvanella*, *Osagia* and *Ottonosia*	1113
5. *Ottonosia* and *Osagia*	1114
6. *Somphospongia*	1115
7. *Anchicodium* and *Somphospongia*	1116
8. *Cryptozoon*	1117
9. Kansas fossil algae	1118
10. *Cryptozoon* and *Osagia*	1119

ABSTRACT

Algal material has been known to exist in the Pennsylvanian and Lower Permian beds of Kansas for many years. Twenhofel described some in 1919, and later writers have repeatedly mentioned their occurrence. Moore (1935) and Elias (1937) pointed

out that they occur quite consistently at certain positions in the depositional cyclothems.

The algae were collected from 74 formations or named formation members which range in age from the top of the Lower Pennsylvanian up almost to the top of the Lower Permian.

The algae described belong mainly to the green and blue-green algae (Chlorophyta and Cyanophyta) and include members of the families Dasycladaceae, Codiaceae, Porostroma and Spongiostroma. The Dasycladaceae are represented by six new species of the genus *Epimastopora*, the Codiaceae by a new genus *Anchicodium* represented by six species. Three species of *Girvanella* are present.

The genera *Ottonosia* and *Osagia* named long ago by Twenhofel are discussed, and details of their microstructures are given. The *Osagia* colonies are shown to consist of an intimate intergrowth of several different algae often associated with Foraminifera belonging to the "*Nubecularia*."

Among the Spongiostroma described are the *Somphospongia* and several species of Cryptozoon.

The importance of the algae as rock builders is considered. Locally they are very important. The relation of the algal deposits to the cyclothems of deposition is noted and discussed.

INTRODUCTION AND ACKNOWLEDGMENTS

Algae have been known from the Pennsylvanian and lower Permian sediments of Kansas for many years. Twenhofel described some in 1919, and later writers have repeatedly mentioned their occurrence. Moore (1935) and Elias (1937) pointed out that they occur quite consistently at certain positions in the depositional cyclothem.

In 1940, under sponsorship of the Kansas Geological Survey, the writer spent several weeks in the field with J. M. Jewett studying the various Pennsylvanian and Lower Permian limestones of Kansas and searching for algal material. About 1000 specimens were collected from approximately 200 localities, and 220 thin sections were prepared. Laboratory studies of the material were made during 1941 and 1942; the work was interrupted by the war until late in 1944 and was completed in 1945. The completion of the study was made possible by a grant from the Penrose Bequest of The Geological Society of America.

The writer wishes to thank R. C. Moore and J. M. Jewett for their assistance in planning the study and in enabling the writer to relate his information on algae to the depositional and ecological data previously obtained by the Kansas Survey. The Colorado School of Mines supplied the laboratory facilities for the study. The manuscript has been read by R. C. Moore.

GEOGRAPHICAL DISTRIBUTION

The collections were obtained from 196 localities in 31 counties in the eastern third of Kansas, and one adjoining county in Oklahoma. Some specimens were also obtained from the Kansas City region in Missouri (Fig. 1).

STRATIGRAPHY

The limestones collected range from the top of the Lower Pennsylvania almost to the top of the Lower Permian. They represent 74 formations or members.

The columnar sections given in Figures 2 to 5 are taken from Moore, Frye, and Jewett's paper (1944). The rock units are described by Moore, Frye, and Jewett (1944).

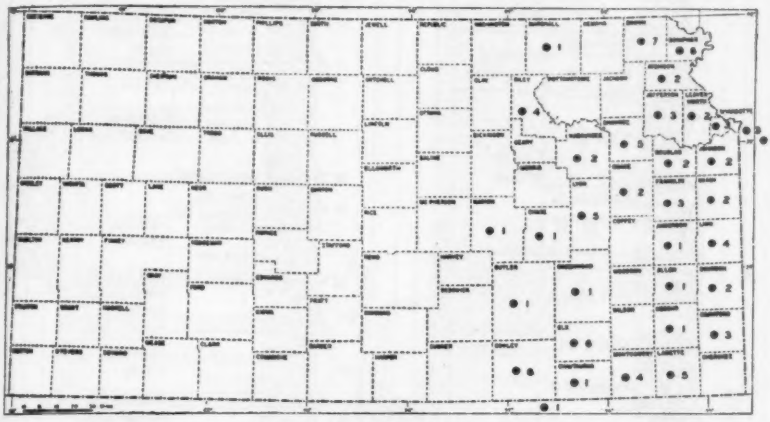

FIGURE. 1.—*Map of Kansas, showing areas where the limestones were obtained*
Counties from which algal material was collected are indicated by circles, and the number of localities in each county by numerals.

LIMESTONES

GENERAL

The limestones cover a wide range of types, including almost all normal marine organic varieties. An effort was made to recognize at least the phylum represented by all the fragments in the organic debris (Table 1).

Table 1 shows the frequency of occurrence of various organic remains in the slides studied, but not the relative importance of the organisms as rock builders. This varies greatly with the formations, but the general order appears as follows: echinoderms (all types together), bryozoa, algae, foraminifers, brachiopods, mollusks.

The relative importance of algae is probably not typical of Pennsylvanian and Lower Permian limestones as a whole because only selected algal limestones or limestones that seemed likely to contain algae were studied.

The limestones will be described in another paper; present discussion is limited to the algae.

ALGAE

CLASSIFICATION

The forms described are classified on the basis of the following features: (1) microstructure, if observable, (2) size and shape of colonies, and (3) growth habits.

The *Solenoporaceae*, Dasycladaceae, and Porostromata show recognizable microstructure as well as definite shape of colony. The *Spongiostroma* are classified only on habit of growth and shape of colony. They may comprise form genera and form species rather than true biologic genera and species. Each form genus and species

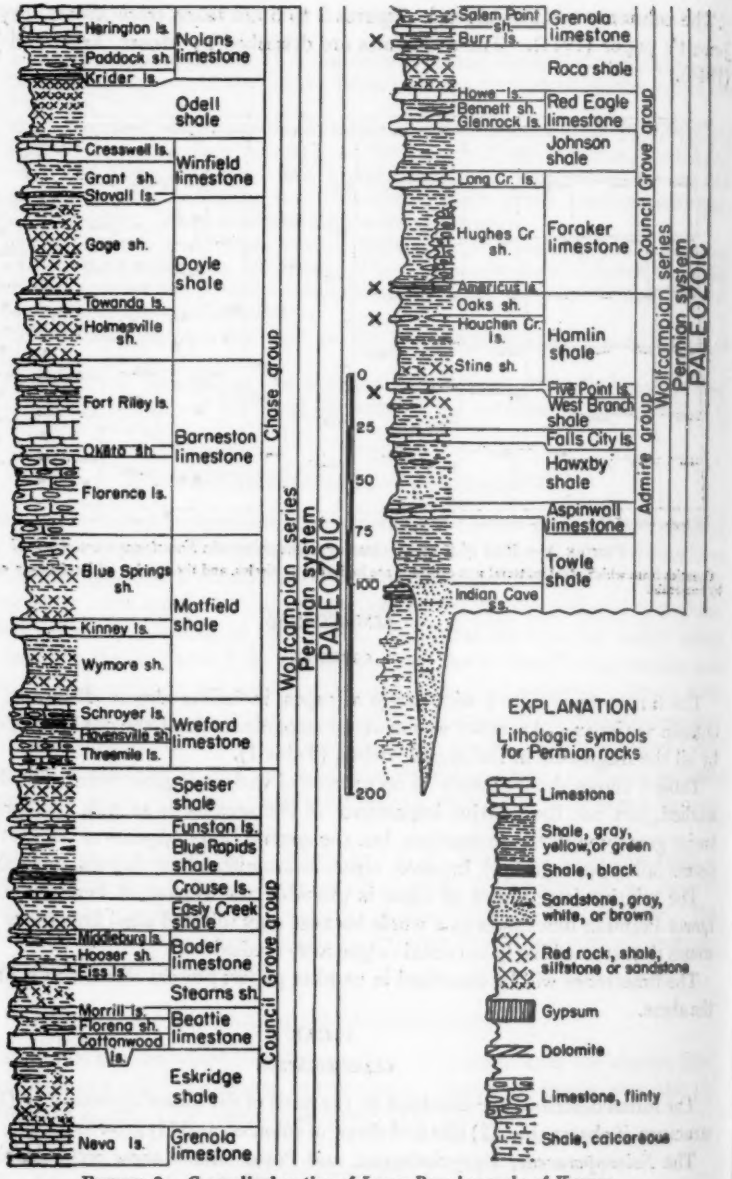

FIGURE. 2.—*Generalized section of Lower Permian rocks of Kansas*
Crosses on left indicate limestones that contain abundant algal material.

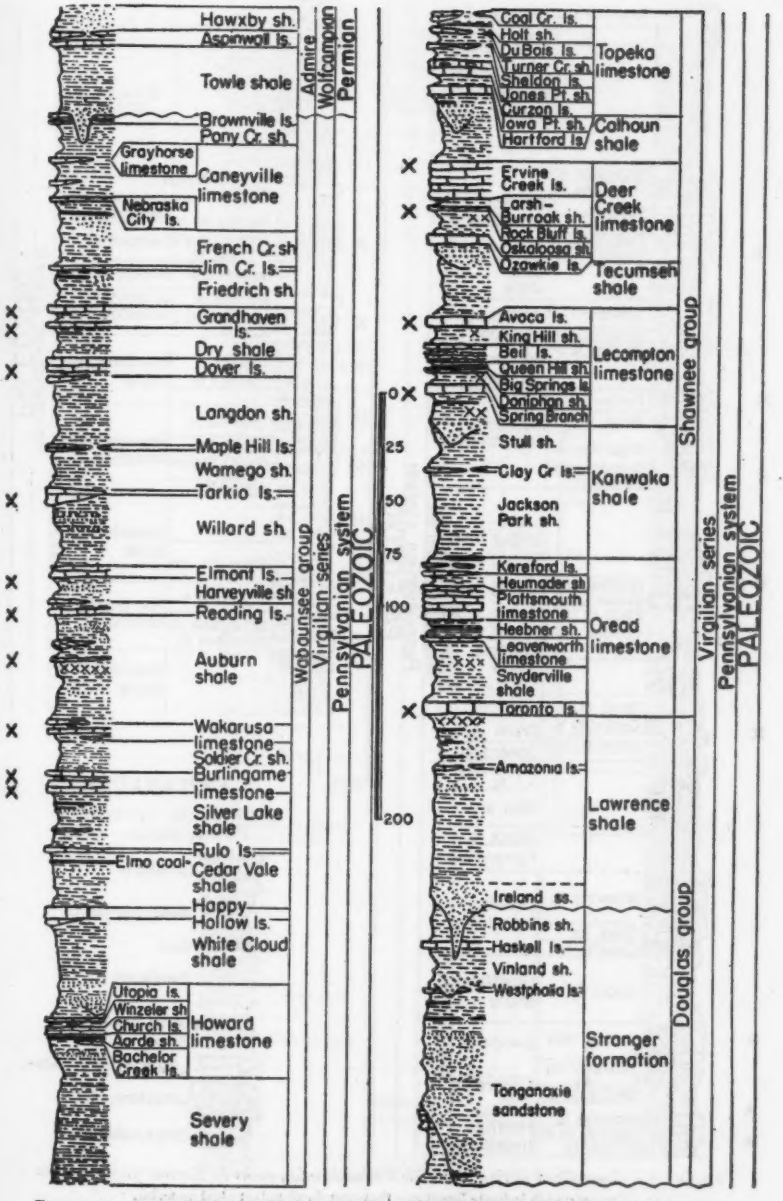

FIGURE 3.—*Generalized section of upper Pennsylvanian rocks in Kansas and Nebraska*
Crosses on left indicate limestones that contain abundant algal material.

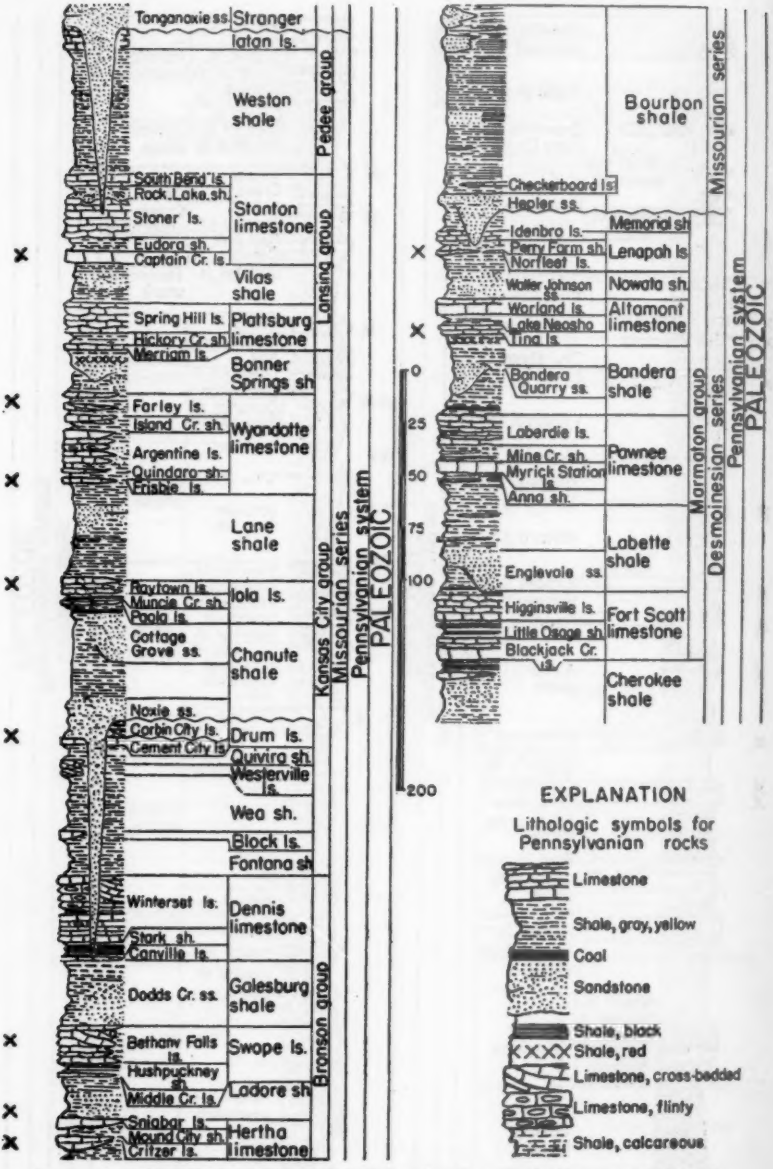

FIGURE 4.—*Generalized section of middle Pennsylvanian rocks in Kansas and Nebraska*
Crosses on left indicate limestones that contain abundant algal material.

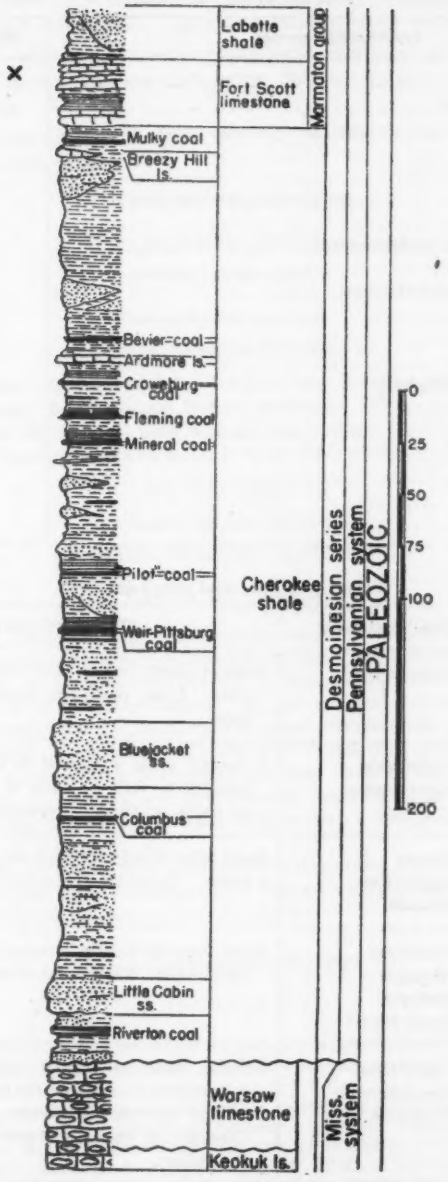

FIGURE 5.—*Generalized section of Lower Pennsylvanian rocks of Kansas and Nebraska*
Crosses on left indicate limestones that contain abundant algal material.

TABLE 1.—*Occurrence of organisms observed in 223 slides*

Type of organic remains	Slides containing remains
Algae	191
Foraminifera (all types)	104
Fusulinids	38
Nubecularia	29
Crinoid fragments	40
Echinoid spines	79
Echinoid plates	10
Echinoderm fragments (undetermined)	34
Bryozoan fragments	104
Molluskan fragments undetermined	2
Gastropod fragments	58
Pelecypod fragments	5
Brachiopod fragments	17
Shell fragments (undetermined)	109
Sponge spicules	6
Coral fragments	5
Ostracods	43
Serpula	2
Trilobite fragment	1
Land-plant spore	

TABLE 2.—*Key to algal groups described*

Class	Family and genera	Characteristic structures
Rhodophyta (Red algae)	Solenoporaceae	Rows of closely packed cells with polygonal cross sections. Cross partitions present, frequently very thin.
Chlorophyta (Green algae)	Dasycladaceae *Epimastopora*	A central stalk, preserved as a tube or bulb, surrounded by tufts of leaves or leaf bases, preserved as knobs or brushlike protuberances.
	Codiaceae *Anchicodium* *Ortonella*	Small tubes loosely arranged so as to form segmented stems. Tubes round in cross section and branching.
Cyanophyta (Possibly Chlorophyta)	Porostromata *Girvanella* *Ottonosia* *Osagia* in part	Small tubes so loosely arranged as not to compress each other. No cross partitions visible.
Cyanophyta (Blue-green algae)	Spongiostroma *Somphospongia* *Cryptozoon*	Cellular structure seldom preserved. The $CaCO_3$ is deposited as crusts on the outside of the colony or cell, or between the tissues, not in the cell wall. Classified on the basis of growth habit and form of the colony.

may represent several biologic species, or even a number of genera and species that lived in constant close association. Such associations, however, permit recognition of the colonies over wide areas through appreciable lengths of geologic time. Different assemblages formed colonies sufficiently different to be separated by megascopic characteristics.

Table 2 summarizes structural characters and classification of the types of algal remains described in this paper.

SYSTEMATIC DESCRIPTIONS

CLASS RHODOPHYTA

ORDER FLORIDEAE

Family Solenoporaceae

Genus *Solenopora* Dybowski

Fragments of material suggestive of *Solenopora* have been found in the Wyandotte (Farley), Oread (Toronto), Foraker (Americus), and Howard limestones. All are too poorly preserved to warrant description and illustration. Good material may be found somewhere in Pennsylvanian rocks, however, since the genus is well known in both the Mississippian and Permian.

CLASS CHLOROPHYTA

SUBCLASS CHLOROPHYCEAE

ORDER SIPHONOCLADALES

Family Dasycladaceae

The Dasycladaceae are nonpartitioned multinucleate algae. Thallus composed of central stem from which whorls of primary branches develop that may bear tufts of secondary and even tertiary branches. Spore cases, or sporangia, may develop (1) within stem, (2) attached to stem, (3) on primary branches, or (4) on secondary branches. Calcium carbonate is precipitated on stem and primary branches, generally covering them, and may cover secondary and tertiary branches.

The fossil usually consists of a hollow calcareous body of spherical, cylindrical, or club-shaped form open at one end and perforated by numerous openings. It is a calcareous mold of the stem, or stem and branches. In Paleozoic and most Mesozoic fossils, openings have been filled with calcite of a texture and tint different from original "wall deposit". Thus, stem and branches appear as canals or pores in the walls.

Fossil Dasycladaceae are known from rocks as old as Ordovician, and a few are recorded from Silurian, Mississippian, and Pennsylvanian deposits. They seem to have been widespread in Permian time, although only a few genera have yet been described.

Genus *Epimastopora* S. Pia, 1922

(Plate 1, figure 1)

The original description of this genus, accompanied by a very hypothetical reconstruction, is inadequate; but Pia (1937, p. 828) has given additional observations, as follows (translation):

"Unfortunately there are only fragmentary pictures available of this fossil and it is very difficult to judge from them the general structure and systematic position. Frequently, these fragments appear straight in thin sections. Sometimes they are curved and in exceptional cases they are S-shaped. If, as I have assumed, these imply remains of spherical bodies, then they must have been several centimeters in diameter .... Recognition of the general form is also made difficult because the skeleton is broken. The fragments are perforated by numerous large, round or polygonal pores."

Pia furnishes no measurements but gives an illustration (reproduced as Pl. 1, fig. 1) that shows essential features. The material is from Lower Permian rocks of the southeastern Alps.

The limestones from Kansas contain abundant pieces of an algal form that exactly fits Pia's picture and description of *Epimastopora*. The specimens represent horizons ranging from low in the Middle Pennsylvanian up to the Lower Permian, as follows: Altamont (Tina), Hertha (Critzer), Lecompton (Spring Branch), Deer Creek (Rock Bluff), Burlingame, and Foraker (Americus and basal Hughes Creek) limestones. In each observed occurrence, this alga is found in the basal member of a formation.

Wood (1943, p. 209) has described a genus called *Koninckopora*, which he considers closely related to *Epimastopora*. The present writer agrees with Wood's judgment as to close relationship of these genera and his interpretation of the thallus of *Epimastopora* as a long cylindrical form, instead of spherical. *Koninckopora* is also cylindrical and is the largest fossil member of the Dasycladaceae yet discovered; it attains lengths of as much as 50 centimeters. *Epimastopora* is also an exceptionally large form. All the Kansas specimens represent fragments; some nearly 2 cm. long show little or no curvature.

Possibly *Epimastopora* and *Koninckopora* are identical, but until well-preserved, reasonably complete specimens of *Epimastopora* are discovered it seems wise to withhold speculation and consider the genera separately.

The Kansas finds are of great interest in elucidating these obscure forms and partially filling the gap in our knowledge of the history of the Dasycladaceae.

Epimastopora kansasensis, n. sp.

(Plate 1, figures 5, 6)

Description based on fragments, mostly long, narrow, and straight, that represent pieces of the calcareous crust deposited around outer tufts of branches. No evidence of central stalk (stem cell) or primary branches. Probably, long slender primary branches extend from stem cell, and tufts of short stubby secondary branches spring from their ends. Some small terminal tufts of tertiary branches observed.

Entire plant must have been large, since fragments up to 1.5 cms. in length show no curvature, tapering, or change in pattern or size of branches.

Thickness of the calcified crust ranges from 0.65 to 0.9 mm.; commonly it is about 0.85 mm. Branches have diameters of 0.05–0.08 mm., and they are spaced at intervals of 0.067–0.011 mm. In fragments which probably came from lower, sterile areas of plant, branches are long and occupy most of the thickness of the crust. Tertiary branches may be present. In pieces from central and upper areas of plant, secondary branches are short and capped by pairs of long slender tertiary branches. No sporangia recognized. Probably they developed from primary branches in uncalcified, hence unpreserved, areas of plant, as in closely related Mississippian genus *Koninckopora*

Outer surface of crust shows numerous round pores closely spaced in irregular rows. Diameter of pores quite constant on single fragment but differs somewhat on different specimens. Range is 0.07 to 0.11 mm., except one specimen in which all are much smaller (0.04 to 0.05 mm.). Distance between pores is about 0.02 mm.

OCCURRENCE: Abundant in basal Lecompton limestone (Spring Branch member), Upper Pennsylvanian, sec. 26, T. 31 S., R. 11 E., Elk County, Kansas.

TYPE: Slide 698, specimen JA2575, Johnson collection, Colorado School of Mines.

REMARKS: This species is described first because much more material was available for its study. than for species from lower beds, and it conveniently serves for comparison with the others. This alga is associated with fragments of shells, Bryozoa, echnoid spines, and numerous other algae, including *Osagia*.

Epimastopora jewetti, n. sp.

(Plate 1, figures 2, 3, 4)

Description based on small fragments, consisting of relatively slender branches having diameters of 0.031–0.065 mm., average about 0.042. They are spaced at intervals of 0.055–0.062 mm. Ter-

tiary branches well developed. The branches are longer and more slender than in *E. kansasensis*. Outside pores large (0.11–0.14 mm.) and widely spaced (0.05–0.1 mm.). They are circular to elliptical in outline. No sporangia observed.

OCCURRENCE: Altamont limestone (Tina limestone member), lower Middle Pennsylvanian, sec. 14, T. 21 S., R. 25 E., Linn County, Kansas.

TYPE: Slide 720, specimen JA2643d, Johnson Collection, Colorado School of Mines.

REMARKS: This species differs from *E. kansasensis* in having more slender branches, better developed, longer and more slender tertiary branches, and larger, fewer, and much less crowded outer pores. It shows features suggestive of *Koninckopora inflata* (de Koninck) but differs in greater branching, lack of constriction of branches, and in the arrangement, size, and spacing of outside pores. This form is associated with fragments of shells, echinoid spines, Bryozoa, small foraminifers, and other algae, including *Girvanella* and small threadlike types.

The species is named in honor of John Mark Jewett of the State Geological Survey of Kansas, who kindly guided the writer on his field trip through Kansas and assisted in collecting material for this study.

Epimastopora regularis, n. sp.

(Plate 2, figures 1, 2)

This species is based on numerous fragments. It is characterized by rather slender branches (diameters 0.03–0.044 mm.) regularly spaced at intervals of 0.08–0.14 mm. Main (secondary) branches frequently bear long tertiary branches. Outer pores circular to slightly polygonal and of moderate size (diameter 0.07–0.09 mm.), arranged in regular rows 0.028–0.033 mm. apart.

OCCURRENCE: Hughes Creek shale and Americus limestone members of the Foraker formation, Lower Permian; sec. 20, T. 10 S., R. 18 E., Riley County, on the outskirts of Manhattan, Kansas.

TYPE: Slide 630, specimen JA233 a, Johnson Collection, Colorado School of Mines.

REMARKS: This species shows the most regular arrangement and size of branches and pores of any observed species of *Epimastopora*. It differs from the others in size of branches and pores; the latter are not nearly so crowded as in *E. kansasensis*. All the specimens studied are coated with *Girvanella* and occur associated with numerous fragments of echinoid spines.

Epimastopora, sp. A

(Plate 2, figure 3)

This form is represented by several small fragments that show slender branches having wide, regular spacing. Branch diameters average 0.05 mm., spaced 0.3 to 0.48 mm. No pieces showing outer pores were found.

OCCURRENCE: Rock Bluff member of the Deer Creek limestone, Upper Pennsylvanian, sec. 22, T. 12 S., R. 18 E., Douglas County, Kansas.

FIGURED SPECIMEN: Slide 555, specimen JA2258E, Johnson Collection, Colorado School of Mines.

REMARKS: The material is too scanty and fragmentary to justify giving a specific name. The specimens are associated with abundant fragments of shells, Bryozoa, crinoids, small gastropods, fusulinids, small foraminifers, *Osagia*, *Girvanella*, and other algae.

Epimastopora, sp. B

(Plate 2, figure 4)

Two fragments having slender, fairly regular and closely spaced branches are here designated *Epimastopora* sp. B. Branch diameters are 0.03–0.05 mm., and spaces between branches are 0.05–0.06 mm. No pieces showing end pores were found. Species is close to *E. regularis*, but differs in

that branches are more closely spaced. Whether this is a specific character or merely results from a different position on the plant is not known.

OCCURRENCE: Burlingame limestone, Upper Pennsylvanian, sec. 5, T. 18 S., R. 13 E., Lyon County, Kansas.

FIGURED SPECIMEN: Slide 621, specimen JA2472, Johnson Collection, Colorado School of Mines.

REMARKS: The available material is too scanty to justify a specific name. The form is associated with fusulinids, small foraminifers, and an abundance of organic fragments representing shells, echinoderms, and Bryozoa. Other algae are abundant, especially *Osagia* and biologically low filamentous types.

Epimastopora, sp. C

(Plate 2, figures 5, 7)

Known only from two fragments. Branches slender and closely spaced, tertiary branches abundant. Small end pores (diameter 0.057 to 0.08 mcm.) moderately spaced in irregular rows *Epimastopora* sp. C differs from *E. kansasensis* and *E. jewetti* in dimensions of branches and pores and in their spacing and arrangement.

OCCURRENCE: Critzer member of the Hertha limestone, Middle Pennsylvanian, sec. 27, T. 21 S., R. 24 E., Linn County, Kansas.

FIGURED SPECIMEN: Slide 728, specimen JA2661, Johnson Collection, Colorado School of Mines.

REMARKS: The material is too scanty and worn to justify a specific name. The specimens are associated with fragments of echnoid spines and Bryozoa, small foraminifers, and other algae, especially *Osagia*.

FAMILY CODIACEAE

Genus *Anchicodium*, n. gen.

Colonies assigned to this genus commence as a crustose mass from which straight or nearly straight cylindrical thalli develop. Thalli may branch or develop rounded protuberances. Some are irregularly constricted, but others are very regular. Each thallus is composed of a spongelike mass of rounded threads or branches. Center tends to be poorly organized or pithlike, but, toward outer margins of thalli, branches tend to become parallel. In some species, branches end in tufts of fine branches that usually are perpendicular to outer surface of thallus. Outer part of thallus calcified, but amount of calcification varies. It may affect only a narrow outer zone or extend inward through entire thallus. Calcified areas usually preserve microstructure, whereas uncalcified portions are filled with clear calcite. No sporangia observed.

RANGE: In the Kansas collection this genus is represented from the upper Middle Pennsylvanian (Captain Creek members, Stanton limestone) into the Lower Permian (Americus members, Foraker limestone).

GENOTYPE: *Anchicodium funile*, n. sp., from Upper Pennsylvanian rocks of Kansas.

REMARKS: In structure, general appearance, and growth habits *Anchicodium* is very similar to the modern *Codium*—hence the name *Anchi* (near) *Codium*. It differs from *Gymnocodium* in having a more slender regular thallus, without deep constrictions and a thick pith. Also, there is no evidence of well-developed sporangia of the type known in *Gymnocodium*. In general, *Anchicodium* seems to have a thallus not so highly organized as in *Gymnocodium*.

Species of *Anchicodium* are differentiated on the basis of diameter of branches, diameter of thallus, and shape and external appearance of thallus. These features seem to be quite constant in specimens from the same formation.

Anchicodium gracile, n. sp.

(Plate 3, figures 1, 2)

Thallus long, slender, cylindrical, and slightly wavy. It pinches and swells slightly. One specimen (Pl. 3, fig. 1) seems to have thick crustlike base from which cylindrical thalli arise. Thallus is

pithlike mass of threadlike branches, which tend to become parallel to each other at outer surfaces of thallus and perpendicular to that surface. Diameter of thallus ranges from 0.385 to 0.50 mm., and its length may be several centimeters. Branches are 0.0045–0.0066 mm. wide.

OCCURRENCE: Abundant in Captain Creek member of the Stanton limestone (upper Middle Pennsylvanian) at the Bert Ross Quarry, SW. 1/4 sec. 6, T. 17 S., R. 20 E., Franklin County, Kansas. A few poorly preserved fragments of the same or a closely related species were obtained from the Toronto member of the Oread limestone (lower Upper Pennsylvanian) in NW. 1/4 sec. 34, T. 17 S., R. 17 E., Osage County, Kansas.

TYPE: Slide 982, specimen JA2430 b, Johnson Collection, Colorado School of Mines.

REMARKS: This species is represented by numerous fragments and a few complete or nearly complete thalli. Specimens are associated with other algae, small foraminifers, and bryozoan shreds.

Anchicodium undulatum, n. sp.

(Plate 7, figure 2)

Thallus long, cylindrical, and undulating. Calcification apparently feeble, inasmuch as only outer portion is commonly preserved. Diameter of thallus 0.286–0.33 mm.; that of the branches is 0.0154 mm.

OCCURRENCE: Top of Big Spring member of the Lecompton limestone (Upper Pennsylvanian), near center sec. 8, T. 9 S., R. 20 E., Jefferson County, Kansas.

TYPE: Slide 637, specimen JA2355, Johnson Collection, Colorado School of Mines.

REMARKS: Observed specimens are associated with fusulinids, small foraminifers, fragments of shells and Bryozoa, and other algae such as coarse *Girvanella* and colonies composed of fine filaments.

Anchicodium nodosum, n. sp.

(Plate 3, figure 5)

Thallus cylindrical but marked by pinching and swelling. Rounded swellings, like buds or incipient branches, develop along thallus. Outer surface and knobs calcified, but calcification is irregular. Branches develop imperfect parallelism at edges of thallus. Diameter of thallus (away from knobs) 0.22–0.55 mm., average 0.44 mm. Branch diameter ranges from 0.016 to 0.04 mm., averages about 0.022 mm.

OCCURRENCE: Ozawkie members of the Deer Creek limestone (Upper Pennsylvanian), NW. cor. sec. 28, T. 4 S., R. 21 E., Doniphan County, Kansas.

TYPE: Slide 648, specimen JA2412, Johnson Collection, Colorado School of Mines.

REMARKS: This alga is associated with numerous fusulinids and smaller foraminifers, algal threads, and *Epimastopora* sp. A.

Anchicodium plumosum, n. sp.

(Plate 2, figure 6; Plate 7, figure 4)

Thallus thick, cylindrical, winding, pinching, and swelling. It has a feathery appearance. Some specimens deeply calcified, especially in area of knobs and swellings. Most of thallus is a spongy mass of branching threads which subdivide abundantly near border. Terminal branches become approximately parallel to each other in a position oblique to outer surface. Diameter of thallus 0.66–1.76 mm., that of branches is 0.0154–0.0198 mm.

OCCURRENCE: Ervine Creek member of the Deer Creek limestone (Upper Pennsylvanian), NE. 1/4 sec. 2, T. 35 S., R. 9 E., Chautauqua County, Kansas.

TYPE: Slide 694, specimen JA2566, Johnson Collection, Colorado School of Mines.

REMARKS: This species has the thickest and seemingly the most spongy thallus of any species observed. It is associated with shell fragments, fine organic debris, and fine algal threads.

Anchicodium funile, n. sp.

(Plate 2, figure 8; Plate 3, figure, 4; Plate 7, figure 1)

Thallus of genotype of *Anchicodium* is cylindrical, long, slender, and ropelike. It may branch or develop rounded protuberances (Pl. 3, fig. 4). Several specimens indicate presence of crusty base from which cylindrical thalli develop. Center of thallus is spongy mass of coarse threadlike branches which bifurcate rapidly and become parallel near the margins where they terminate in brushy clusters of short branches perpendicular to outer surface. Diameter of thallus (average, not protuberances) 0.03–0.035 mm. Thalli to 3 cm. long are observed. Diameter of ordinary branches 0.14–0.17, and that of fine terminal branches about 0.007 mm.

Occurrence: Abundant in Wakarusa limestone and Auburn shale, less common in the Burlingame limestone. Localities: Wakarusa limestone sec. 5, T. 18 S., R. 13 E., Lyon County; NE. sec. 16, T. 3 S., R 18 E., Brown County: Auburn shale, sec. 34, T. 11 S., R. 14 E., Shawnee County: Burlingame limestone, NW. sec. 27, T. 35 S., R. 18 E., Labette County, Kansas.

Type: Slide 666, specimen JA2479, from the Wakarusa limestone, Johnson Collection, Colorado School of Mines.

Remarks: This species attains the greatest lengths of any form of *Anchicodium* studied. It is associated with fusulinids, small foraminifers, small gastropods, and other algae.

Anchicodium permianum, n. sp.

(Plate 7, figures 3, 7)

Thallus of this form, which pinches and swells, is rather slender. Calcification weak and usually limited to narrow outer crust. Branches fine, have diameter of 0.007–0.009 mm. Diameter of thallus 0.275–0.32 mm.

Occurrence: Americus member of the Foraker limestone (Lower Permian), sec. 36, T. 4 S., R. 9 E., Marshall County, Kansas.

Type: Slide 596, specimen JA2336, Johnson Collection, Colorado School of Mines.

Remarks: This species is represented by numerous fragments that are coated by *Ozagia* and *Girvanella*.

CLASS CYANOPHYTA (POSSIBLY CHLOROPHYTA)

Family Porostroma

Genus *Girvanella* Nicholson and Etheridge, 1880

Girvanella moorei, n. sp.

(Plate 3, figure 6)

Characterized by tubular filaments surrounded by well-defined wall. No evidence of branching. Filaments twist and entwine in spaghettilike mass which forms spherical or lozenge-shaped colonies or coatings around other fossils. Tube diameters 0.017–0.019 mm., and thickness of walls is about 0.008 mm.

Occurrence: Type material is from Tina member of Altamont limestone (lower Middle Pennsylvanian), sec. 14, T. 21 S., R. 25 E., Linn County, Kansas. Specimens of *Girvanella* having similar dimensions, presumably representing the same species, are observed in the Lenapah, Hertha, Ladore, Wyandotte (Farley member), and Oread (Plattsmouth member) of Middle and Upper Pennsylvanian.

Type: Slide 719, specimen JA2641, Johnson Collection, Colorado School of Mines.

Remarks: The species is named in honor of Raymond C. Moore, who greatly assisted the present study. Among described species of *Girvanella*, *G. ducii* Wethered, from the English Mississippian,

which has a tube diameter of 0.02 mm., most closely resembles *G. moorei*. Observed examples of this species are associated with fragments of shells, echinoid spines, small foraminifers, and algae, including *Epimastopora jewetti*, other *Girvanella*, and threadlike types.

Girvanella maplewoodensis Johnson

Girvanella maplewoodensis, J. H. JOHNSON, 1946, Jour. Paleontology, vol. 20, no. 2, p. 169, plate 30, fig. 4.

Represented by fine, twisting, tubelike algal threads having well-defined walls. They coat fragments of organic debris, so as to produce rounded pellet-shaped colony. Diameter of threads is 0.008–0.009 mm.

OCCURRENCE: Altamont, Lenapah, and Hertha limestones, Bethany Falls member of the Swope limestone, Middle Pennsylvanian, of Labette and Linn counties, Kansas. Altamont limestone NW. sec. 36, T. 32 S., R. 19 E., Labette County; Lenapah limestone SW. sec. 1, T. 3 S., R. 18 E, Labette County; Bethany Falls member of Swope limestone SE. sec. 36, T. 19 S., R. 24 E., Linn County, Kansas.

FIGURED SPECIMEN: Slide 737, specimen JA2706, from the Altamont Limestone, Johnson Collection, Colorado School of Mines.

REMARKS: In general appearance and diameter, specimens from Pennsylvanian rocks of Kansas are identical with examples of *Girvanella maplewoodensis* Johnson described from Mississippian beds at St. Louis, Missouri. Kansas specimens are associated with numerous small foraminifers, few fusulinids, fragments of echinoid spines and plates, Bryozoa, and algae.

Girvanella magna, n. sp.

(Plate 4, figure 1)

This species comprises slightly twisted and entwined coarse algal tubes having well-defined walls. They occur loose in rock groundmass and coat fossil debris so as to make small rounded colonies. Tube diameter 0.039–0.041 mm. Walls 0.008–0.009 mm. thick.

OCCURRENCE: Type material of this species is from Lenapah limestone, Middle Pennsylvanian, in sec. 1, T. 33 S., R. 18 E., Linn County, Kansas. Species also observed in Critzer member of Hertha limestone.

TYPE: Slide 740, specimen JA2715, Johnson Collection, Colorado School of Mines.

REMARKS: One of the largest described forms of *Girvanella*. It is associated with small foraminifers, shell and echinoderm fragments, and with abundant lower types of algae.

Girvanella sp. aff. *G. ducii* Wethered, 1890

Girvanella ducii WETHERED, 1890, Geol. Soc. London, Quart. Jour., vol. 46, p. 280, pl. 11, figs. 2a, b, c.

(Plate 4, figure 2)

Twisted and entwined tubular algal filaments having diameter of 0.0225–0.0286 mm. They coat organic fragments producing rounded colonial masses and less commonly occur independently as small irregular bodies.

OCCURRENCE: Upper Pennsylvanian, Big Spring member of the Lecompton limestone, N. sec. 8, T. 9 S., R. 20 E., Jefferson County; top Elmont limestone and Tarkio limestone, both at sec. 28, T. 10 S., R. 9 E., Riley County, and Lower Permian, Americus member, Foraker limestone, sec. 36 T. 4 S., R. 9 E., Marshall County, Kansas.

REMARKS: Appearance, tube dimensions, and mode of occurrence agree with Wethered's description of *Girvanella ducii* from the Mississippian of Gloucestershire, England.

Pia (1937, p. 820) mentions occurrence of a *Girvanella* from the Permian near Orenburg, Russia, in which diameter of tubular filaments varies greatly but is commonly 0.02–0.025 mm. He does not

illustrate or name the form. *G. aff. ducii* has a diameter within the range of the Russian specimens and is intermediate between *G. moorei* (0.0176 mm.) and *G. magna* (0.039 to 0.041). Associated with other algae, including *Anchicodium permianum* and *Osagia*.

CLASS CYANOPHYTA?

Family Porostromata

Genus *Ottonosia* Twenhofel, 1919

Ottonosia laminata Twenhofel

(Plate 4, figure 6; Plate 5, figures 1–4)

Ottonosia laminata Twenhofel, 1919, Am. Jour. Sci., 4 th ser., vol. 48, p. 350, fig. 4.

Twenhofel's original description is as follows:

"Irregularly shaped coenoplases which begin as incrustations around other substances and increase in size through the deposition of material over and around that already deposited. The diameters vary up to about 85 millimeters. Most of the coenoplases are biscuit-shaped; a few are spherical. In small specimens the shapes appear to have been determined by the shapes of the nuclei. One specimen which has the convex valve of a Derbya for a nucleus still retains that shape, the shell being covered with about one eighth inch thickness of algal material. The exteriors are irregular through the presence of little cylindrical-sided domes and their separating depressions. The elevations arise from one another and there is great irregularity in shapes, sizes and degrees of divergence.

"The interior structure consists of very thin and closely placed concentric laminae and these repeat the irregularities of the exteriors. A depression on the surface is apt to be continued into the interior by small lines or streaks of fine sand and mud. These streaks are interpreted as arising from small quantities of mud and sand becoming lodged in the depressions between the domes. Some tubelike structures which penetrate portions of the interior may have been produced by the boring of annelids or mollusks, or they may be molds of the thalli of algae. These are also filled with fine sand and mud. The laminae vary in thickness; at one place eight were distinguished in a thickness of five millimeters; at another place only five laminae are present in the same thickness."

Specimens studied by Twenhofel show little in way of microstructure beyond laminae or growth layers. During present study, specimens found reveal microstructure, showing the laminae composed of threadlike filaments 0.009–0.017 mm. in diameter, with an average of 0.0115 mm. These are arranged more or less parallel with the surface in the thin laminae (Pl. 5, figs. 2, 4), but in thicker laminae they may also form rounded or dome-shaped masses of radiating threads (Pl. 5, fig. 3). Branching of filaments is common in the latter, and tufts of branches may occur.

Occurrence: Crouse limestone (Lower Permian), Cowley County, Kansas, and Osage County, Oklahoma. A good locality is a road cut in the Crouse limestone just north of the middle of sec. 11, T. 34 S., R. 7 E., Cowley County, Kansas.

Figured Specimens: Slides 681 and 682, specimens JA2530 and 2533, Johnson Collection, Colorado School of Mines.

Remarks: Pia (1937, p. 818), following Twenhofel's description, classes this genus in the family Spongiostromata on the basis of its lack of internal structure. Microstructure, however, shows that *Ottonosia* belongs in the family Porostromata.

Colonies or "biscuits" of this form are locally so abundant as to fill zones a foot thick which can be traced for several miles.

Genus *Osagia* Twenhofel, 1919

(Plate 2, figures 3–5; Plate 4, figures 3–5; Plate 5, figures 5, 6; Plate 10, figure 2)

Twenhofel founded this genus on specimens from the Foraker limestone (Lower Permian) in Ekler Canyon, Cowley County, Kansas. Unfortunately, type specimens are so filled with limonite as to obscure microstructure. In the present study, algae of this type were the most common and wide-

spread forms studied. Locally colonies are so common that geloogists of the Kansas Survey have termed such *Osagia*-rich algal limestones "osagite".

The description of *Osagia* given by Twenhofel (1919, p. 351) is as follows:

"The Foraker limestone (Permian) of southeastern Cowley County, Kansas, and Osage County, Oklahoma, particularly in some of the Ekler Canyon exposures, in some horizons contains an abundance of algal coenoplases (colonies) of small size. The shapes are such that on casual examination they are apt to be mistaken for *Fusulina*. It is possible that these coenoplases may represent a new species of *Ottonosia;* but, as none attains a large size and the concentric laminae do not appear to be wrinkled, they are considered the type of a new genus. This view is strengthened by the tendency to develop a fusiform shape. Thin beds of limestone are almost wholly composed of these algal remains.

"When first discovered it was thought that possibly these structures might have developed through the chemical inorganic precipitation of material around nuclei. This led to a search for oolite and pisolite. None has been found, and it is quite certain that they do not occur in association. This fact, considered in connection with the additional fact that no matter what the nucleus may be, a fusiform shape tends to be developed, makes it quite certain that they are of organic origin.

"The coenoplases are about the shape and size of *Fusulina*, but are generally a little larger and more robust. Each has a small fragment of rock or shell for a nucleus. In one observed instance the nucleus consists of a small pellet of fine-grained sand and mud. It is probable that anything would serve. Dimensions range to a length of about 7 millimeters and a thickness of about 4 millimeters. The exteriors are imbedded in the rock, but they appear to be smooth or only slightly irregular. The interior structure consists of thin concentric laminae of which there are from 4 to 6 to a millimeter. No radial structures of any kind were observed.

"All of the specimens are so discolored by limonite that it was not possible to photograph them in thin section. The greater part of the limonite occurs within the coenoplases, the surrounding matrix generally being composed of quite clear calcite. It is considered quite certain that the limonite was precipitated in the coenoplase at the time it was formed and that there is some genetic connection between the limonite and the algae which were responsible for the coenoplases.

"In method of development the coenoplase of this genus resembles all others of concentric laminated structure. The small size, the general absence of a wrinkled exterior, and the tendency to assume a fusiform shape are rather marked features of difference.

"The generic name is taken from Osage County, Oklahoma, on the northern border of which the coenoplases occur in abundance. The genotype is Osagia incrustata, n. sp."

MICROSTRUCTURE: Study of many thin sections from Pennsylvanian rocks shows that colonies classed as *Osagia* consist of intimate intergrowth of algal filaments of different sizes presumably representing algae of several types. Permian specimens consist of intergrowth of such algae with coarse tubular foraminifer belonging to the genus "*Nubecularia*." The nature of assemblage varies in different formations, but at a given horizon the combination is surprisingly consistent, and resulting colonies are quite uniform in size and shape.

A typical *Osagia* colony starts with a nucleus consisting of some fragment of organic debris, such as piece of brachiopod or mollusk shell (Pl. 4, fig. 4), part of a bryozoan zoarium, crinoid ossicle (Pl. 4, fig. 5), or echinoid spine or plate. Foraminifera or fragments of higher algae may serve as the nucleus. A coating of intergrown algae or of algae and *Nubecularia* grows around the nucleus rather uniformly at first but tends to concentrate along top and sides as the deposit thickens, so as to develop a rounded lozenge or bean-shaped colony (Pl. 4, figs. 3, 4). Table 3 records dimensions of *Osagia* colonies from several horizons.

STRATIGRAPHIC VARIATION: In lower Middle Pennsylvanian rocks, colonies of *Osagia* are built largely or entirely by algae having fine tubular filaments of type long known as Girvanella. Specimens of *Osagia* from younger beds show that fine algal threads become more and more abundant and make up a larger proportion of the colony. *Nubecularia* has been found in colonies from the Iola limestone, the lowest known occurrence of this foraminifer, and the genus appears at intervals in the succeeding Pennsylvanian, especially toward the top. In Permian rocks *Nubecularia* seems to be present invariably and forms a large portion of the colonies. Some zones above the Foraker limestone contain not only compound colonies of *Nubecularia* and algae, but also large colonies of *Nubecularia* associated with few, if any, algae. The first type of colonies retains general characteristics of *Osagia*, but the second type consists of irregular coatings and plumy growths that differ from normal *Osagia*. The latter become well developed in the Funston limestone (Pl. 9, fig. 6). The two types of growth commonly occur in the same limestones throughout overlying parts of the marine Permian sequence in

Kansas up to the Fort Riley limestone. Neither growth form has been observed above the Fort Riley, which may signify incomplete collections or, more probably, a change in ecological conditions. The constitution of *Osagia* colonies, as observed from Altamont to Fort Riley in Kansas, is summarized in Table 4.

TABLE 3.—*Measurements of* Osagia *sp. in millimeters*

	Formation	Large coarse tubes	Coarse tubes	Fine tubes	Threads	Fine threads	Thickness coating	Size colony (length)
LOWER PERMIAN	Fort Riley ls.	0.09 ± N*	0.0308 G*			0.0027–0.0036		2.65 ±
	Funsten ls.	0.035–0.048 N	0.09		0.008	0.0036		
	Morrill ls.	0.065 N	0.04 G	0.0153		0.0027–0.0036	0.022 ±	7.70 x 0.66
	Neva ls.	0.33–0.44 N			0.0176 G	0.004	0.165	1.32 x 0.33
	Burr ls.	0.024–0.013 N			0.0045 G	0.0018–0.0027		
	Roca shale	0.05	0.0198–0.0176			0.0036	0.22–0.33	3.41 x 0.44 1.54 x 0.99
	Hughes Creek shale	0.048–0.064		0.012 G	0.0063	0.0045	0.44–0.66	2.9–3.5
	Foraker ls. undivided	0.05–0.06				0.0036	0.22–0.66	1.2 x 1.6 av
UPPER PENNSYLVANIAN	Grand Haven ls.	0.033 ± N	0.15–0.02			0.0035–0.0045	0.22	2.97 x 0.66 v.
	Elmont ls.	0.0315–0.018 N			0.09	0.0036	0.27–0.038	3.30 ±
	Reading ls.				0.0075–0.0081		0.45–0.38	5.3 ±
	Burlingame ls.			0.0135–0.017	0.0099	0.0027–0.0038	0.75–1.0	3.0–7.3
	Severy shale	0.036–0.04 N	0.0225	0.0135	0.0072	0.0027–0.0018		
	Deer Creek ls.	0.092 N	0.242			0.002–0.005	0.55	0.9–3.69
	Oread ls. (Toronto)	0.088	0.035		0.008	0.003	0.27–0.55	5.80
MIDDLE PENNSYLVANIAN	Stanton ls. (Captain Creek)	0.0484			0.009–0.008	0.003	0.44–1.1	
	Iola ls. (Raytown)	0.07–0.09 N			0.005–0.006	0.0045–0.0054		
	Snibar ls.	0.066–0.057 N	0.02–0.026	0.017	0.007–0.008	0.003		
	Critzer ls.	0.073–0.045	0.0171 G	0.0171 G		0.003	0.55 mm.	1.20 mm. ±
	Lenapah ls. (Top)	0.045–0.032 G	0.0176 G		G 0.0075–0.008	0.0027–0.004		
	Altamont ls.			G 0.014–0.018		0.0027–0.0036		

*N = Nubecularia.
G = Girvanella.

Twenhofel gave his specimens from the Foraker limestone the specific name *Osagia incrustata*. Study by the writer, as outlined above, shows that, instead of being a true biological species, this fossil represents merely a growth form. Since colonies of *Osagia* are so constant in a given formation, however, they may be treated as form genera and species of lower algae described from the Paleozoic. Changes from formation to formation are so slight that it is extremely difficult to differentiate distinct species. Consequently, no attempt is made to subdivide them; all forms are designated as ***Osagia* sp.**

CLASS CYANOPHYTA

FAMILY SPONGIOSTROMA

Genus *Somphospongia* Beede, 1899

(Plate 6, figures 1, 2; Plate 7, figures 5, 6, 8)

One of the most spectacular of Pennsylvanian algae. Early geologists observed it and considered it of uncertain affinities. Beede (1899, p. 128) described it as a sponge, giving the following generic description:

"A globular to mushroom-shaped calcisponge, attaining a large size, and generally possessing a more or less spherical-shaped cloaca near the base; the canals are all very irregular and crooked, distributed over the entire surface, and moderately large. A rather thick dermal layer is present. They were free, apparently resting with the base in the mud in the adult stage."[1]

During the 1930's Harold Hawkins, M. K. Elias, W. H. Schoewe, and others of the Kansas Geological Survey staff collected considerable material which was studied by Hawkins and Elias. They determined it was a calcareous alga. Hawkins prepared a paper on the subject, which was given orally at a scientific meeting, but, unfortunately, never published.

Moore (1935, p. 217) reports *Somphospongia* from the Burlingame formation and states that these growths "are believed to be algal." Elias (1937, p. 411) lists *Somphospongia* among the calcareous algae and states that it is not a sponge.

A large number of specimens were collected for the present study. From them the following revised description has been prepared: globular, egg-shaped to mushroom-shaped calcareous algae. Young colony spherical to biscuit-shaped, but as it becomes larger it tends to become inverted conical or mushroom-shaped. Surface irregular, covered with folds, crenulations, or digitate projections. Several small colonies may start separately and then coalesce.

REMARKS: Usually the colony starts as an incrustation around a nucleus consisting of a shell fragment, mud ball, or some other small foreign body. The incrustation is composed of finely laminated layers having a concentric arrangement. After growth has attained a thickness of 0.5–1 cm., digitate processes develop and grow out in all directions. When colony reaches a thickness of more than 2 cm., growth seemingly is concentrated on the upper surface, and digitate processes develop, become long, and may branch. The spaces between are filled with clay particles and fine silt.

Microscopic study shows that the colony is formed of laminae composed of fine branching algal threads enclosing sedimentary particles and some organic debris. Most threads have a diameter of 0.007 mm., but associated with them are some larger ones (diameter 0.024 mm.). The laminae are alternating light and dark; the light ones are thicker. They are irregular, and some have crenulated margins. They are composed of molds of fine algal threads in very fine-grained calcite. Some fine clay and silt particles are enclosed. Dark layers contain more foreign material and carbonaceous matter. Probably the laminae represent seasonal growth.

Average-sized colony is slightly conical, with gently rounded upper surface, and measures about 9 cm. high and 8 cm. at the greatest diameter, just below the top, but colonies may grow much larger. Largest specimen studied measures 13 cm. high and 12 cm. wide. Compound colonies, starting as a number of separated forms that coalesce above, measure more than 30 cm. across.

Somphospongia multiformis Beede

(Plate 6, figures 1, 2; Plate 7, figures 5, 6, 8)

Somphospongia multiformis, J. W. BEEDE, 1899, Kans. Univ. Quart., vol. 8, p. 128, pl. 38, figs. 1–10; 1900, Univ. Geol. Survey Kans., vol. 6 p. 12–13, pl. 1, figs. 6–10, pl. 2, figs. 1–5.

This is the type species of the genus and the only one named. It was defined in the description and discussion of the genus. The form is quite variable.

OCCURRENCE: Abundant in the Burlingame limestone (Upper Pennsylvanian) in eastern Brown, northwestern Atchison, and western Doniphan counties. A good locality is the road cut in NW. ¼ sec. 11, T. 4 S., R. 18 E., Brown County, Kansas.

Genus *Cryptozoon* Hall, 1884

(Plate 8, figures 1, 2; Plate 9, figure 5; Plate 10, figure 1)

Algal colonies of *Cryptozoon* type are common in some limestones, especially the Grand Haven, Dover, Wakarusa, Church member of the Howard, and the Avoca member of the Lecompton. They are usually considerably smaller than the much better known *Cryptozoon* of the pre-Cambrian, Cambrian, and Ordovician.

Typical colony is composed of thin concentric growth laminae. Colony generally commences to grow around a nucleus of foreign material, commonly a fossil or fragment of a fossil. Silt, fossils, and fragments of fossils may be enmeshed in the colony, especially between the laminae.

Laminae composed of fine, mostly branching threads of simply organized algae, probably Cyanophyaceae. Originally these formed a spongy mass. Very fine-grained calcium carbonate was deposited around algal filaments. When the plant died, molds of threads were left, forming a very porous calcareous mass that was easily dessolved by percolating waters and often recrystallized. As a result, details of the algal threads are discernible but are seldom clearly shown.

TABLE 4.—*Characters of the genus* Cryptozoon

Formation	Description	Size colony (average) (centimeters)	Size composing algal threads (millimeters)	Species
Wreford limestone	Rounded cabbagelike, coarse concentric laminae. (Laminae 0.01–0.04 cm.)	Average 16 x 11 x 20 Some much larger.	0.007–0.008	*C. wrefordensis*
Grand Haven limestone	Small rounded colonies with thin concentric layers.	4 x 3 x 2.2	±0.008	*C. kansasensis*
Dover limestone	Irregular, small shallow colonies with thin concentric layers.	6 x 3 x 0.7	±0.008	*C. kansasensis*
Reading limestone	Small rounded to oval colonies, thin laminae.	5 x 9 x 4	0.008	*C. kansasensis*
Wakarusa limestone	Small flat colonies, thin laminae.	4.5 x 2 x 0.75	0.0036	*C.* Sp. A
Howard limestone (Church member)	Irregular. Small flat colonies, thin laminae.	3 x 2 x 0.8	0.008	*C. kansasensis*
Deer Creek limestone (Ervine Cr. member)	Small rounded colonies, thin laminae.	7 x 2.5 x 4	0.008	*C. kansasensis*
Lecompton limestone (Avoca member)	Small rounded, very thin laminae.	4 x 3 x 3	0.009 to 0.01	*C. kansasensis*
Iola limestone (Raytown member)	Slender, irregular colonies, very fine laminae.	3 x 2 x 0.5	0.008	*C. kansasensis*

Algae of this type are known from the pre-Cambrian to the Present. They represent colonies of biologically low types of algae. It is questionable whether the colonies could be classified as genera or species in the true biologic sense, but various types remain surprisingly constant in form, size, shape, and constituent algal filaments over wide areas throughout long periods of time; so it is customary to class them as form genera and species and name them like true genera and species.

Cryptozoon kansasensis, n. sp.

(Plate 8, figures 1, 2; Plate 9, figure 5)

This species comprises small flattened round colonies having thin concentric growth laminae. They are composed of branching algal threads 0.008 mm. in average diameter.

OCCURRENCE: Pennsylvanian of Kansas, especially in upper limestones of regressive stage of cyclic deposits. Common in Dover, Grand Haven, and Reading limestones, but not limited to them (Table 4).

TYPE: Specimens JA2306, 2459, Johnson Collection, Colorado School of Mines.

REMARKS: Colonies occur separately and in crowded masses that show considerable variation in

shape and size. *Cryptozoon kanasasensis* differs from *C. coloradoensis* Johnson, the nearest described species, in development of a smaller, flatter colony, having finer growth laminae, and being composed of much finer algal threads.

Cryptozoon wrefordensis, n. sp.

(Plate 10, figure 1)

Rounded, cabbagelike colonies having coarse concentric growth laminae, and about the size of cabbages. Algal threads have diameter of 0.007–0.008 mm.

OCCURRENCE: Wreford limestone (Lower Permian), road cut about 1.5 miles north of Otto, in NW. ¼ sec. 18, T. 34 S., R. 7 E., Cowley County, Kansas.

TYPE: Slide 680, specimen JA2528, Johnson collection, Colorado School of Mines.

REMARKS: This is the largest *Cryptozoon* found in the Carboniferous of Kansas. It is larger and has coarser growth laminae than *C. coloradoensis*, and algal threads are much finer. It differs from *C. kansasensis* in being much larger and more rounded, and having much coarser growth laminae. The constituent algal threads are all approximately same size.

Cryptozoon sp. A

Colonies here indicated are similar in general shape and appearance to *Cryptozoon kansasensis* but differ in the size of the algal threads (diameter 0.0036 mm.).

OCCURRENCE: Wakarusa limestone (Upper Pennsylvanian) from a number of localities in Brown County, especially NE. sec. 16, T. 3 S., R. 18 E., Brown County, Kansas.

ALGAL THREADS

Nearly all the slides studied show some final algal threads (*e.g.*, Pl. 9, figs. 3, 4), and in some limestones they are quite common. Usually preserved as molds in very fine-grained calcite (algal dust). Seem to represent remains of common algae of very simple structure. They are disseminated through groundmass, but some coat fossils and fossil fragments. May form fairly well-defined rounded colonies or appear as irregular dark masses.

The thread dimensions show great variation, ranging from extremely fine (0.003 mm.) to fairly coarse (0.02 mm.). Many branch. Presumably a number of algal genera are represented, but observed data are too meager to permit classification or to justify application of names.

PERFORATING ALGAE

Many examples of perforating algae have been observed in this study. They are present in most of the limestones examined. These algae generally consist of very fine algal threads (average diameter 0.0027–0.0036 mm.) which coat and penetrate fragments of fossils, especially shells, echinoderms, and the larger foraminifers. Where the algal threads are abundant, they appear to have caused a chemical alteration and disintegration of the shell or echinoderm plate or stem segment.

ALGAL DEPOSITS

GENERAL STATEMENT

Algae play a three-fold role in the formation of limestones: (1) as active contributors, (2) as incidental contributors, and (3) as disintegrating agents.

Several limestones studied are essentially algal in that the algae were the principal contributors to rock building. *Osagia*, *Cryptozoon*, *Ottonosia*, and *Somphospongia* are especially important in making limestones. In other limestones, algae and foraminifers were the principal contributors; other organisms are present but play a minor role as rock builders.

Colonies of algae, especially those of biologically higher types, are present along with fossils of other kinds in many limestones. They form an interesting but subordinate element and contribute only a small fraction of the bulk of these limestones. This is true for *Epimastopora* and most occurrences of *Anchicodium*.

The groundmass of some limestones consists of a mat of threadlike algal filaments and fine silt or organic debris enclosing foraminifers, larger fossils, and fossil fragment. Some algal threads are present in the groundmass of about 85 per cent of these limestones, but they are a predominant constituent only in approximately 20 per cent of the slides.

Fine algal threads commonly coat and perforate fossils and fossil fragments. These seem to have affected the fossils both mechanically and chemically, causing or assisting in their disintegration.

ECOLOGY

In the systematic discussion of the algae, associated organisms have been listed, generally in order, to give the reader an idea of the ecology. Results of this study may be summarized briefly as follows: (1) Some algae were present in all the marine environments involved; (2) the majority of lime-secreting algae are associated with molluscan and mixed faunas; (3) some algae occur with the presumably deeper-water fusulinid faunal group.

RELATION OF ALGAL DEPOSITS TO CYCLOTHEMS

Moore (1930; 1931), Elias (1937), Jewett (1941), and various others have noted that Pennsylvanian and Permian rocks of Kansas show definite cyclic deposition. Numerous cyclothems repeat lithologic sequences and fossil faunas.

While some calcareous algae may occur in any of the limestones, and even some of the shales, most of the algal limestones occur in the bottom and top limestone members of a limestone formation (Figs. 2–5). This confirms the observation of Elias (1937) on the Permian Big Blue series. The exceptions are certain phases of the fusuline-bearing limestones which may develop highly algal facies.

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Colorado School of Mines, Golden, Colorado

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EXPLANATION OF PLATES

PLATE 1.—EPIMASTOPORA

FIGURE

1.—*Epimastopora* sp. Pia 1937 (×12). Lower Permian, Trogkofelkalk, Carnic Alps.

2–4.—*Epimastopora jewetti* n. sp. Altamont limestone, Linn County, Kansas. 2 (×25) shows longitudinal sections; 3, same (×45), longitudinal section showing details of branching; 4, same (×25), showing top and side views.

5, 6.—*Epimastopora kansasensis* n. sp. Lenapah limestone, Elk County, Kansas. 5 (×30), side view showing branching; 6, same, top view showing the "pores".

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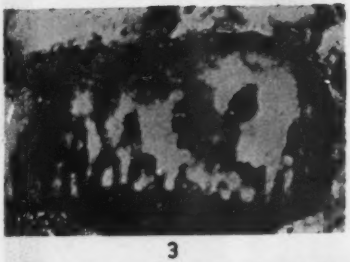

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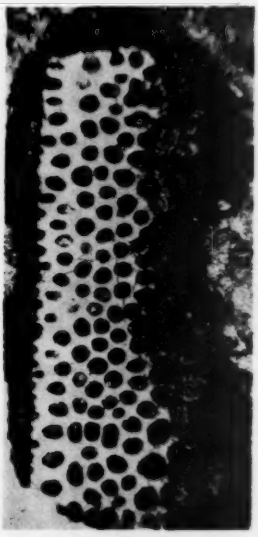
EPIMASTOPORA



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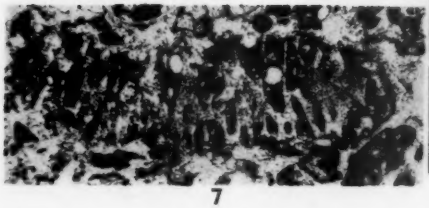

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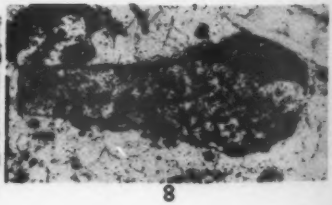

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EPIMASTOPORA AND ANCHICODIUM

PLATE 2.—EPIMASTOPORA AND ANCHICODIUM

FIGURE

1, 2.—*Epimastopora regularis* n. sp. Hughes Shale member, Foraker formation, Riley County, Kansas. 1 (×25), top view showing spacing and regular arrangement of "pores"; 2 same, (×25), side view.

3.—*Epimastopora* sp. A. Deer Creek formation, Douglas County, Kansas (×30). Small fragment shown at top. *Osagia* colony and organic debris below.

4.—*Epimastopora* sp. B. Burlingame limestone, Lyon County, Kansas (×25). Side view, coated with *Osagia*.

5, 7.—*Epimastopora* sp. C. Upper Hertha formation, Linn County, Kansas (×25). 5, top view showing pores; 7, same side view showing the very slender branches.

6.—*Anchicodium plumosum* n. sp. Ervine Creek limestone, Deer Creek formation, Chautauqua County, Kansas (×30).

8.—*Anchicodium funile* n. sp. Auburn shale, Shawnee County, Kansas (×35).

PLATE 3.—ANCHICODIUM AND GIRVANELLA

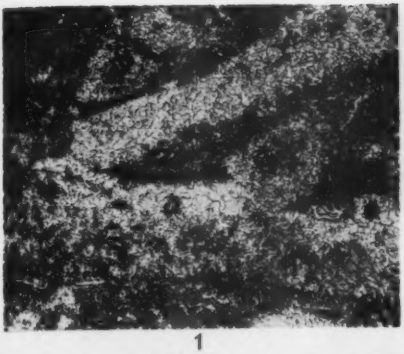
FIGURE

1, 2.—*Anchicodium gracile* n. sp. (×40), Captain Creek member of the Stanton formation, Bert Ross Quarry, Linn County, Kansas.

3, 4.—*Anchicodium funile* n. sp. 3 (×50), Auburn shale, Shawnee County, Kansas, shows nodes; 4 (×18), Wakarusa limestone, Lyon County, Kansas, a number of colonies showing branching and nodes.

5.—*Anchicodium nodosum* n. sp. (×30), Ozawkie member, Deer Creek formation, Doniphan County, Kansas.

6.—*Girvanella moorei* n. sp. (×55), Altamont limestone, Labette County, Kansas.



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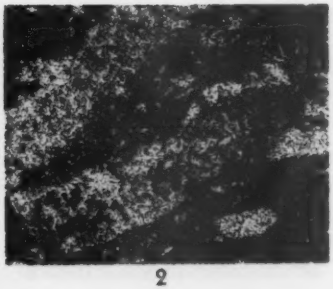

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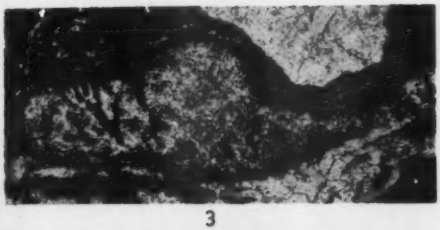

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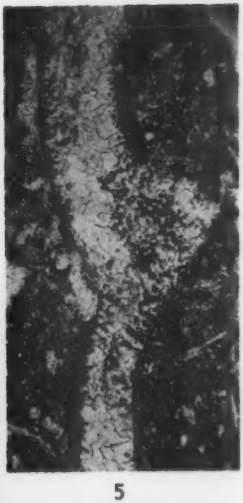

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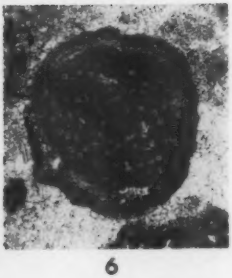

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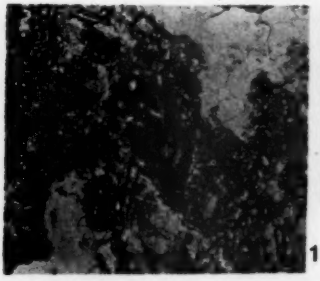
ANCHICODIUM AND GIRVANELLA



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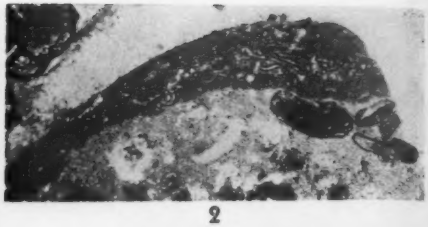

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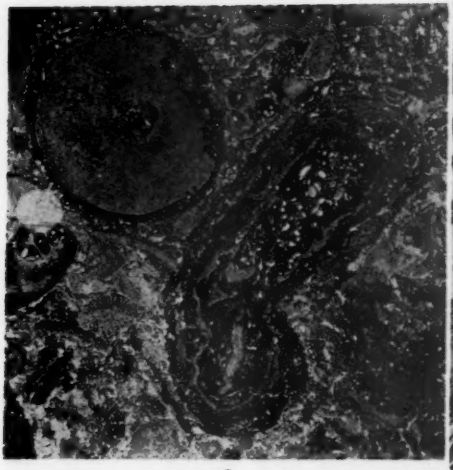

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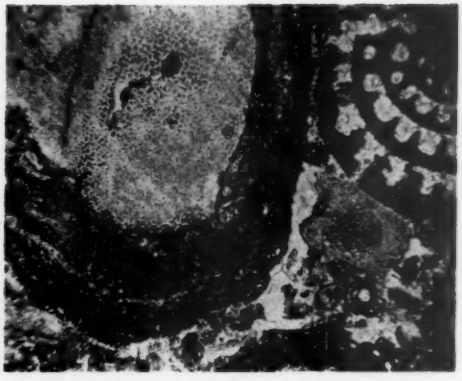

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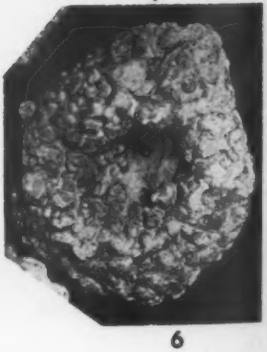

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GIRVANELLA, OSAGIA, AND OTTONOSIA

PLATE 4.—GIRVANELLA, OSAGIA, AND OTTONOSIA

FIGURE

1.—*Girvanella magna* n. sp. (×35), Lenapah limestone, Linn County, Kansas.

2.—*Girvanella cf. ducii* (×30), Foraker limestone, Marshall County, Kansas.

3.—*Osagia* (×15), Fort Riley limestone, Cowley County, Kansas. Shows a characteristic colony containing *Nubecularia*, *Girvanella*, and fine algal threads. A segment of a crinoid stem is in upper left. It is coated with dark algal threads.

4.—*Osagia* (×25), Hertha limestone, Linn County, Kansas. A typical colony containing *Nubecularia* and algae around a nucleus of shell fragment.

5.—Portion of an *Osagia* colony on a crinoid plate (×25), Burlingame limestone, Lyon County, Kansas. Fusulinid at right.

6.—*Ottonosia laminata* Twenhofel (×3/4), Crouse limestone, Cowley County, Kansas. Under side of a colony.

PLATE 5.—OTTONOSIA AND OSAGIA

FIGURE

1.—*Ottonosia laminata* Twenhofel. Type specimen (×1). Crouse limestone, Cowley County Kansas.

2.—*Ottonosia laminata* Twenhofel (×40), Crouse limestone, Cowley County, Kansas. Microstructure, the laminae are composed of a map of branching algal filaments.

3.—Same as Figure 2 (×55). Shows branching and somewhat radiating algal filaments in a thick lamination or growth layer.

4.—Same (×55). Inclosures of other material among the algal filaments in thin laminae.

5.—*Osagia* sp. (×25), Hertha limestone, Linn County, Kansas. Typical colony around a shell fragment.

6.—*Osagia* sp. (×25), Foraker limestone, Osage County, Oklahoma. Portion of an *Osagia* colony around a fragment of a fossil. Shows the *Nubecularia* chamber walls (white) and algal threads (dark).

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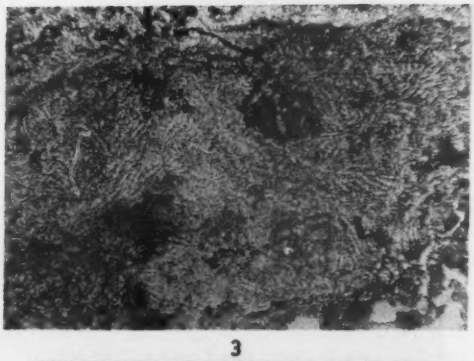

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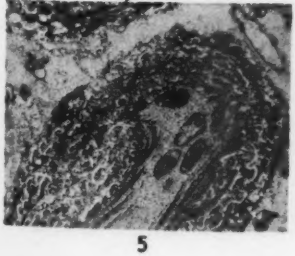

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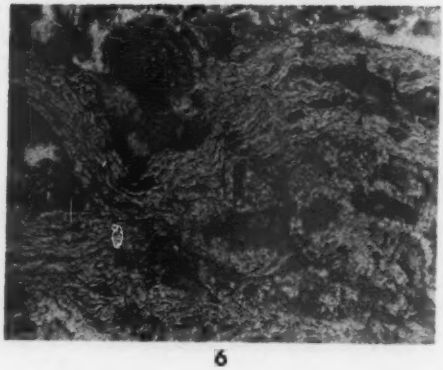

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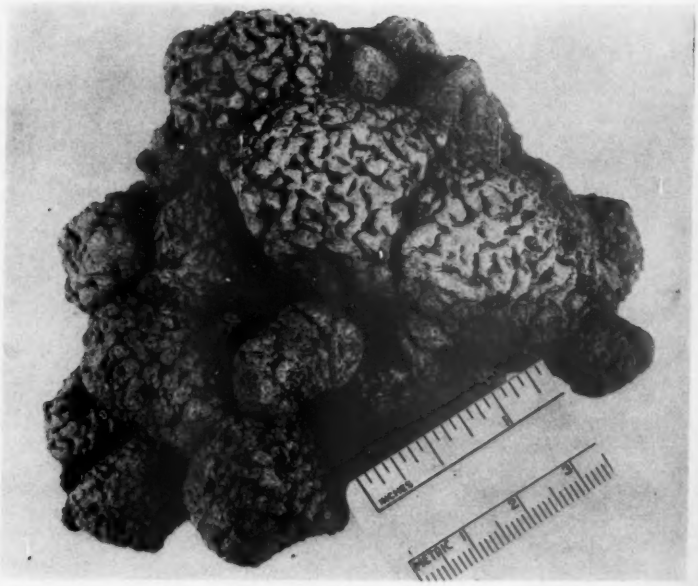
OTTONOSIA AND OSAGIA



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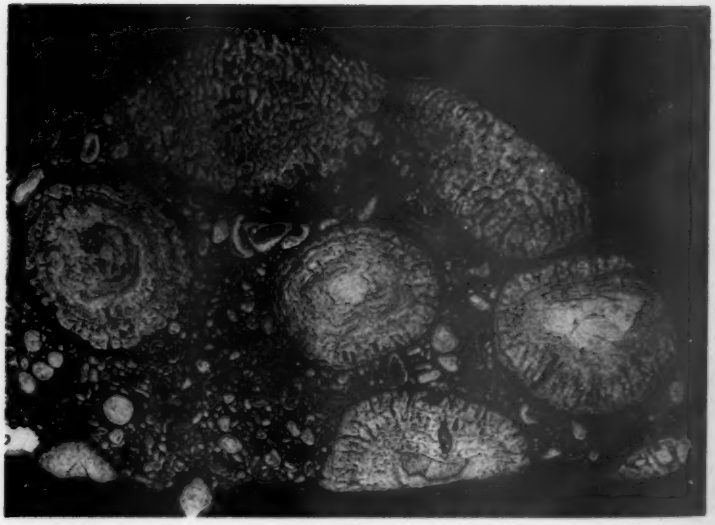

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SOMPHOSPONGIA

PLATE 6.—SOMPHOSPONGIA

FIGURE

1.—*Somphospongia multiformis* Beede, Burlingame limestone, Brown County, Kansas. A small specimen showing top views of a number of intergrown colonies.

2.—The same (×2/3). A larger specimen, from the same locality, eroded and etched. Shows nucleus, early laminations, later knobs, and digitate growths.

PLATE 7.—ANCHICODIUM AND SOMPHOSPONGIA

FIGURE

1.—*Anchicodium funile* n. sp. (×32), Wakarusa limestone, Brown County, Kansas.

2.—*Anchicodium undulatum* n. sp. (×32), Lecompton limestone, Jefferson County, Kansas.

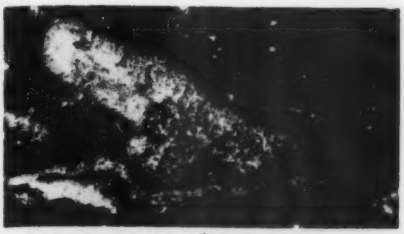
3.—*Osagia* coating *Anchicodium permianum* n. sp. (×25), Americus limestone member of the Foraker formation, Marshall County, Kansas.

4.—*Anchicodium plumosum* n. sp. (×30), Ervine Creek limestone, Deer Creek formation, Chautauqua County, Kansas.

5, 6.—*Somphospongia multiformis* Beede (×25), Burlingame formation, Brown County, Kansas.

7.—*Anchicodium permianum* n. sp., coated with *Osagia* (×25), Americus limestone member of the Foraker, Marshall County, Kansas.

8.—*Somphospongia multiformis* Beede (×35), Burlingame formation, Brown County, Kansas.



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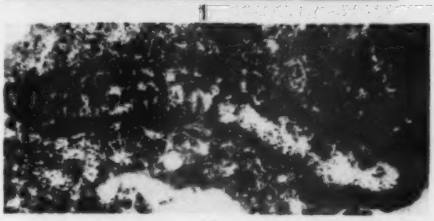

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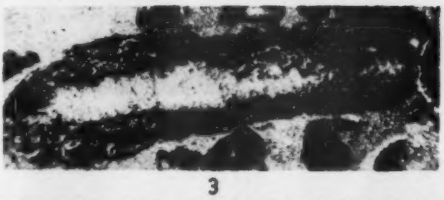

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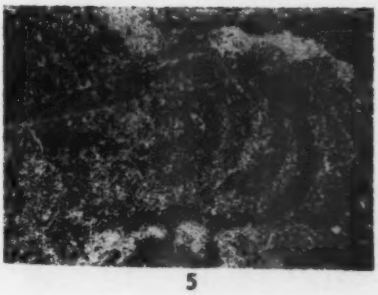

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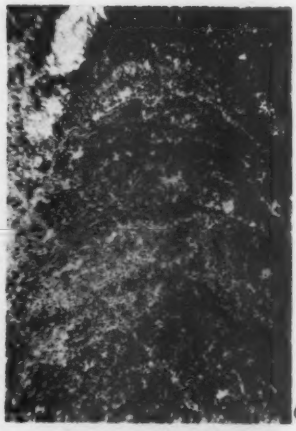

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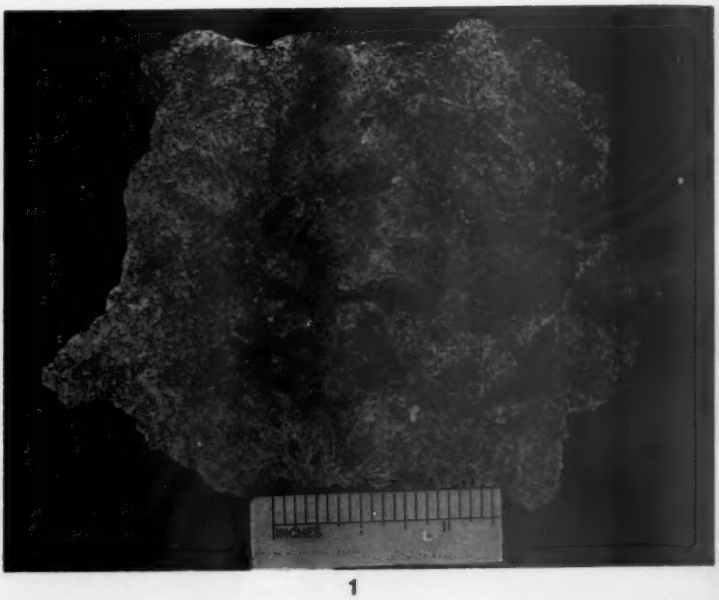
ANCHICODIUM AND SOMPHOSPONGIA



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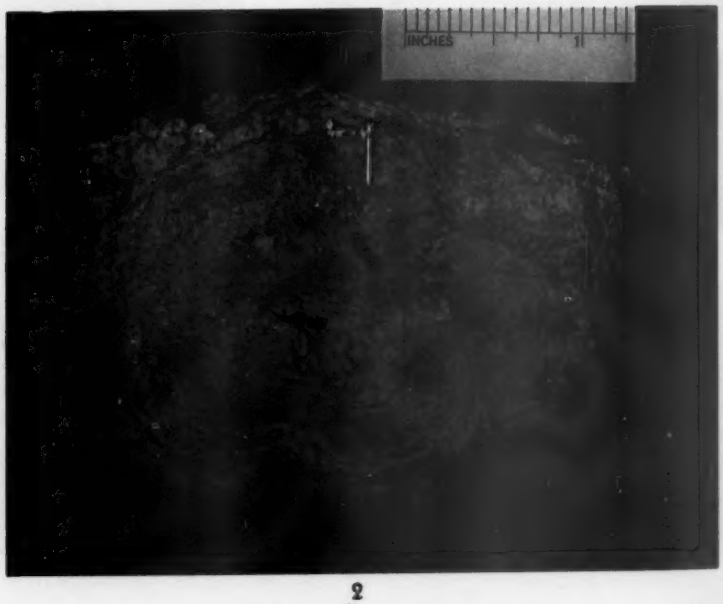

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CRYPTOZOON

PLATE 8.—CRYPTOZOON

FIGURE

1.—*Cryptozoon kansasensis* n. sp. (about ×1), Dover limestone, Wyandotte County, Kansas. Weathered hand specimen.

2.—*Cryptozoon kansasensis* n. sp. (about ×1), Reading limestone, Lyon County, Kansas. Hand specimen, weathered and etched.

PLATE 9.—KANSAS FOSSIL ALGAE

FIGURE

1.—Fine algal threads (black) between corallites of a *Chaetetes* coral colony (×25), Higginsville limestone, Fort Scott formation, Crawford County, Kansas.

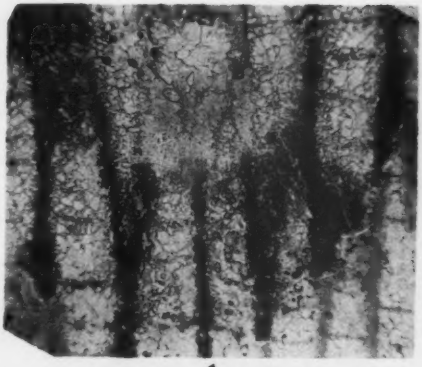
2.—*Girvanella maplewoodensis* Johnson (×50), Altamont limestone, Labette County, Kansas.

3.—Mat of fine branching algal threads (×30), Ladore shale, Kansas City, Missouri.

4.—A mat of fine algal threads form most of the groundmass (×25). Ardmore limestone, Crawford County, Kansas.

5.—*Cryptozoon kansasensis* (×30), Lecompton limestone, Elk County, Kansas.

6.—Plumose *Nubecularia* colony (×25), Funston limestone, Wabaunse County, Kansas.



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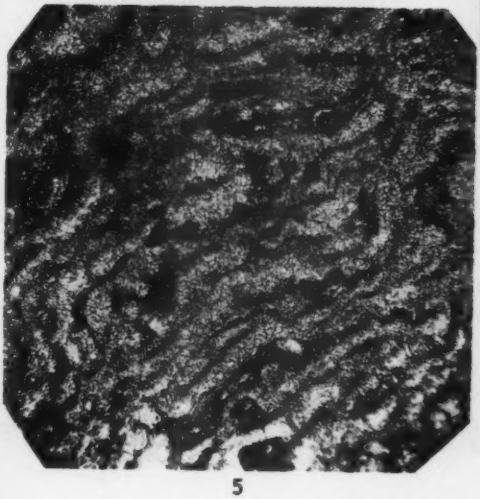

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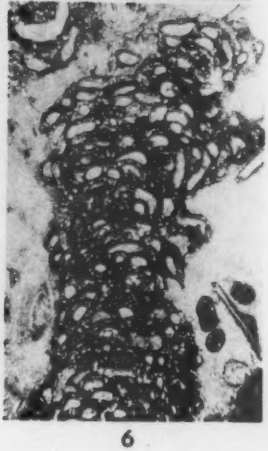

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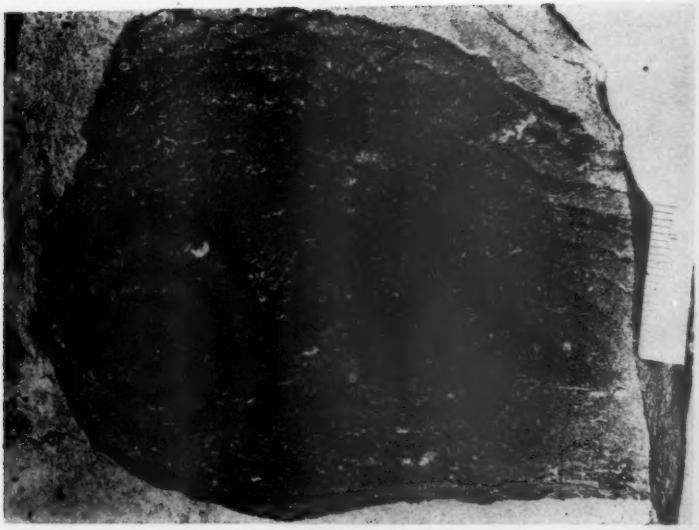
KANSAS FOSSIL ALGAE



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CRYPTOZOON AND OSAGIA

PLATE 10.—CRYPTOZOON AND OSAGIA

FIGURE

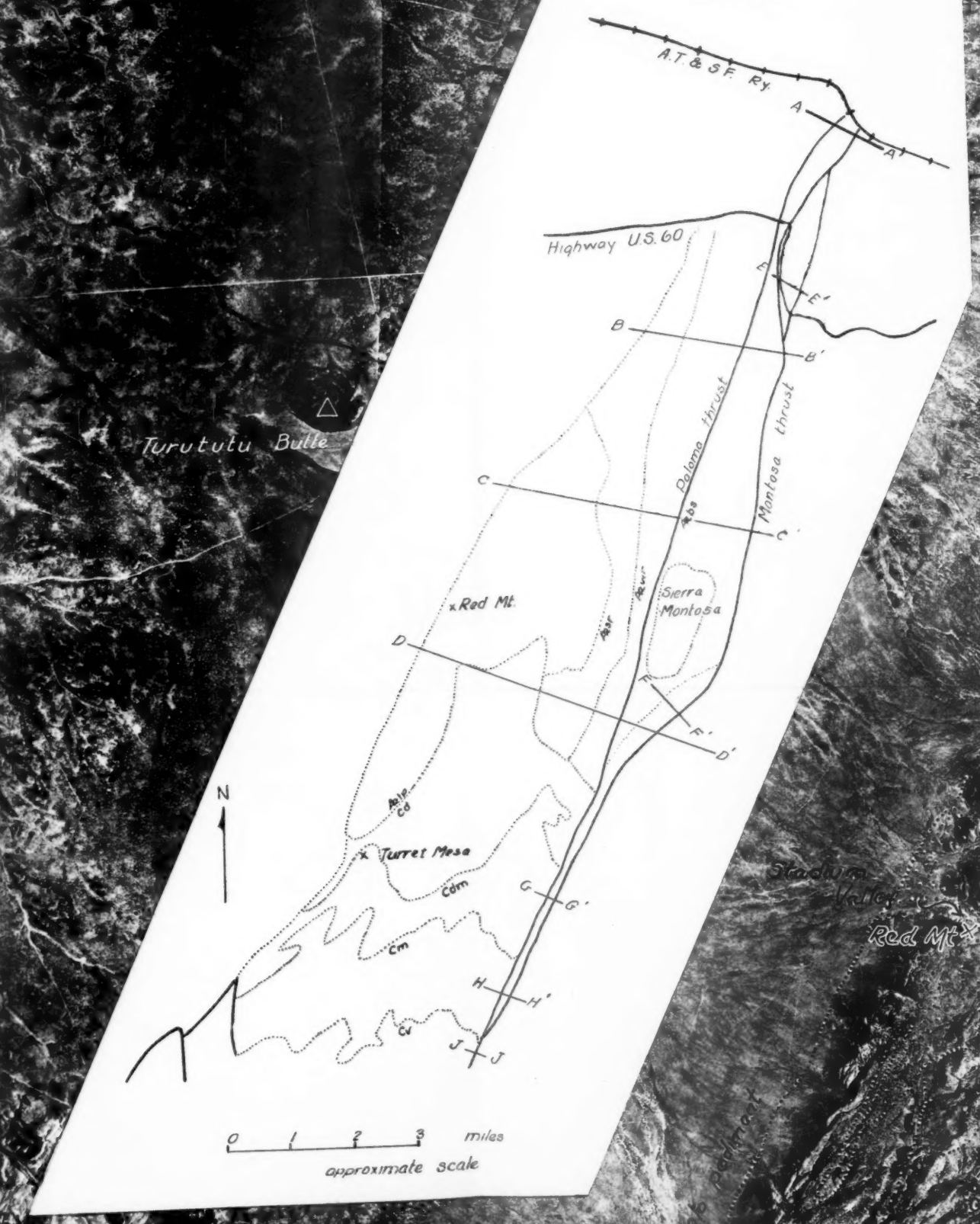
1.—*Cryptozoon wreffordensis* n. sp., Permian, Wreford limestone, near Otto, Cowley County, Kansas.

2.—*Osagia* colony (×40), showing the large tubes and chambers of *Nubecularia* and the dark mat of coarse and fine algal filaments. Permian, Crouse limestone.

3.—*Osagia* limestone (×1), showing abundant colonies of *Osagia*. Pennsylvanian, Upper Hertha limestone.

106°45'
34°30'

Location Of Structure Sections



106°30'

34°30

Of Structure
Sections

SF. Ry.

A A'

E E'

B B'

Montosa thrust

Montosa thrust

Arroyo Abo

Blue Spgs

White Face Peak

Sand Canyon

Abo Pass

Abo Canyon

Salado Canyon

Dripping Spgs.

Highway US-60

Indian Knob

Porter Ranch

Montosa

Stadium Valley

Red Mt.

Tongue Ridge

Mt. Paloma

thrust

LEGEND

QUATERNARY	Qb	Basalt
TERTIARY	Ta	Andesite
PERMIAN	Cy	Yeso formation
	Ca	Abo formation
	Cat / Catl	Aqua Torres formation — limestone member
PENNSYLVANIAN	Cv	Virgil series
	Cm	Missouri series
	Cdm	Des Moines series
	Cd	Derry series
PRE-CAMBRIAN	Arlp	Los Pinos granite — granitized sediments
	Arsr	Sevilleta rhyolite

Location of cross Sections

Turututu Butte

Antonio Arroyo

Abo Pass

Dripping Spg

White Face Peak

Indian Knob

Red Mt.

Stadium Valley

Mt Palomas

Montosa Thrust

Barrel pedimat

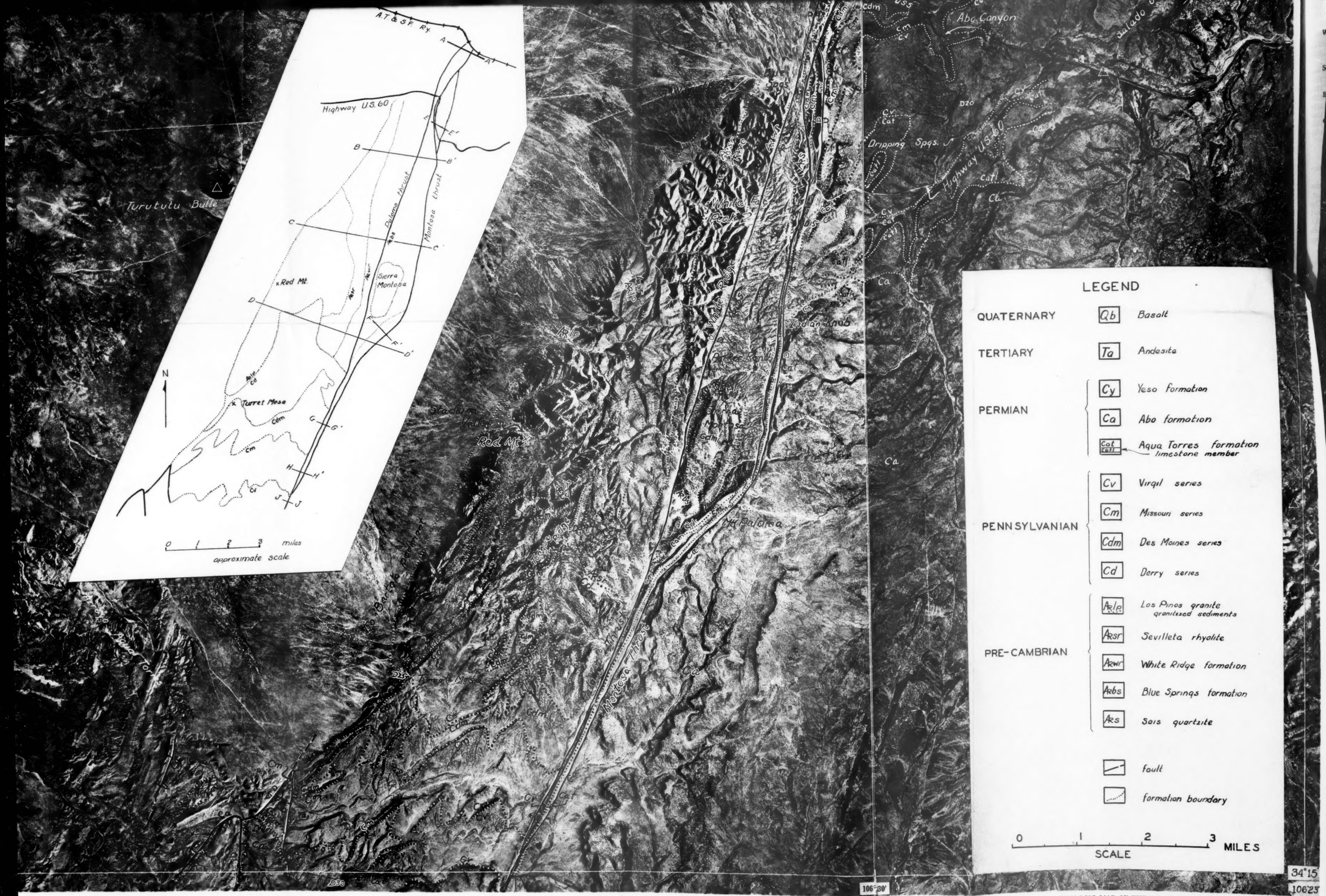
Tower Ridge

Turret Mesa

34°15'

106°45'

106°30'


A.T. & S.F. Ry.
Highway U.S. 60
Dripping Spgs.
Abo Canyon
Salado Cr.
Turututu Bulle
White Peak
Red Mt.
Sierra Montosa
Turret Mesa
Stadium Valley
Indian Knob
Table Mt.
Tongue ridge
Bursum Ranch
Palomas
Montosa thrust
Palomas thrust
Baldy Peak
Pinos Peak
Pinos Wells
Pinos Altos
Pinos Ranch
Pinos Creek
Pinos Wells Creek
Pinos Altos Creek
Pinos Ranch Creek
Pinos Wells Quadrangle
Pinos Altos Quadrangle
Pinos Ranch Quadrangle
Pinos Wells Mountains
Pinos Altos Mountains
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GEOLOGY OF THE LOS PINOS MOUNTAINS, NEW MEXICO

BY J. T. STARK AND E. C. DAPPLES

CONTENTS

	Page
Abstract	1122
Introduction	1123
Location and extent	1123
Field work	1123
Acknowledgments	1124
Physiography	1125
General statement	1125
Stream pattern	1126
Pre-Cambrian	1127
General lithologic features	1127
Sais quartzite	1127
General statement	1127
Lithology	1128
Thermal metamorphism	1129
Blue Springs schist	1130
General statement	1130
Lithology	1130
Thermal metamorphism	1131
White Ridge quartzite	1133
General statement	1133
Lithology	1134
Border facies	1134
Selvilleta rhyolite	1134
General statement	1134
Lithology	1135
Basic schists	1135
General statement	1135
Lithology	1136
Granite—Los Pinos facies	1136
General statement	1136
Lithology	1137
Granite—Priest facies	1138
General statement	1138
Lithology	1139
Correlation of the granites	1139
Pegmatite and aplite dikes	1140
Quartz and quartz-feldspar dikes	1140
General statement	1140
Lithology	1140
Metamorphism of the pre-Cambrian rocks	1140
General statement	1140
Regional metamorphism	1141
Thermal metamorphism	1141
Dynamic metamorphism	1142

Page

Paleozoic strata ... 1143
Pennsylvanian ... 1143
General features ... 1143
Cyclical sedimentation ... 1145
Rock types ... 1145
Cycles within series ... 1149
Permian ... 1153
General features ... 1153
Aqua Torres formation ... 1154
Abo formation ... 1155
Yeso formation ... 1155
Permian-Pennsylvanian boundary ... 1156
Structure ... 1156
General statement ... 1156
Pre-Cambrian basement ... 1157
Los Pinos granite ... 1158
Faulting ... 1159
General statement ... 1159
Paloma thrust fault ... 1159
Montosa thrust fault ... 1160
Folding associated with faulting ... 1161
Cross faulting and shearing ... 1162
Classification of the thrust faults ... 1162
Associated block faulting ... 1163
Age of thrusting ... 1163
Mountain border fault ... 1164
Summary of geologic history ... 1164
Measured stratigraphic sections ... 1165
References cited ... 1171

ILLUSTRATIONS

Figure Page

1. Sketch map of New Mexico ... 1124

Plate Facing page

1. Geologic map of the Los Pinos Mountains, New Mexico ... 1121
2. Cuestas and faults ... 1124
3. Pediment and nodular limestone ... 1125
4. Stratigraphic sections of pre-Cambrian rocks ... 1128
5. Fault breccia and limestone hog back ... 1160
6. Structures associated with the Montosa thrust fault ... 1161
7. Structure sections across Los Pinos Mountains, New Mexico ... 1162

ABSTRACT

The Los Pinos Mountains form the southern part of a northward-trending mountain group along the Rio Grande Valley in central New Mexico.

The pre-Cambrian core, the area of greatest relief, is composed of the Sias quartzite (oldest), Blue Springs muscovite schist (originally siltstones), White Ridge quartzite, and Sevilleta rhyolite, all intruded by the Los Pinos (pre-Cambrian) granite. The pre-Cambrian bedded rocks exceed 12,000 feet in thickness, of which over 4500 feet is rhyolite flows. All dip westward (average 50°), and schistosity parallels the dip. Schistosity of the Los Pinos granite (N. 20° E.) parallels that in other pre-Cambrian

rocks. Granitization is pronounced along its borders, particularly along the contacts with the White Ridge quartzite. The pre-Cambrian rocks have been subjected through a long period of time to numerous environmental changes giving rise to several types of metamorphism, commonly superimposed upon one another. Early regional metamorphism is partly obliterated in thermally metamorphosed aureoles around the granite intrusions. In many zones widespread dynamic metamorphism has completely destroyed the effects of earlier regional and thermal metamorphic changes.

Pennsylvanian and Permian strata unconformably overlie the pre-Cambrian rocks; they form cuestas on the east and south sides of the uplift, whereas, on the western flank, a normal fault downthrown on the west is suggested. The Pennsylvanian rocks consist of nonmarine sandstone and shale grading upward into marine limestone and shale. The latter commonly grade upward into nonmarine sandstone. Permian "red beds" (Abo sandstone) appear to lie conformably upon the Pennsylvanian. The stratigraphy is described in detail, and measured sections are given of the Derry, Des Moines, Virgil, Missouri, and Aqua Torres series.

Pre-Cambrian rocks have been thrust eastward overturning the Paleozoic sediments. Such faulting (Laramide) consists of two closely spaced north-south-trending thrust slices (40–60-degree dips), the Montosa and Paloma. Some bedding-plane movements and normal faulting followed the thrusting.

INTRODUCTION

LOCATION AND EXTENT

The extension of the Southern Rocky Mountains into New Mexico terminates at the southern limits of the Sangre de Cristo Range. Here the mountain front is topographically offset to the west before continuing southward as a much less imposing range separated into three semi-isolated units by low passes. These units are, in order from north to south, the Sandia, Manzano, and Los Pinos Mountains (Fig. 1). The Los Pinos lie between the latitudes of 34° 16′ and 34° 27′ north and are separated topographically from the Manzano Mountains by a small tributary of the Rio Grande, Arroyo Abo. This gorge has been cut into a wide, flat terraced surface where the mountains narrow to their minimum width, and where their elevation has been reduced to approach that of the great pediment surface bordering the western face of the mountains. Southward from Arroyo Abo, the areally lens-shaped mass of the Los Pinos Mountains trends S. 20° W. for 15 miles, widens in the central part to somewhat more than 4 miles, and narrows again at the souther end. Here the limit of the mountains is an arbitrary boundary where cuestas of Pennsylvanian and Permian rocks merge into the dissected plateau farther south.

FIELD WORK

During the summer of 1941, the authors spent 8 weeks studying the structure and stratigraphy of the Los Pinos Mountains. Short traverses were made into the southern part ot the Manzano Mountains north of Abo Pass (Arroyo Abo), and reconnaissance studies of border areas were carried out only insofar as seemed necessary to clarify the relationships of the formations in the Los Pinos Mountains. Aerial photographs, scale 1:63, 360, were used as base maps upon which to indicate the geology. A small part of the eastern slopes of the range has been surveyed by town-

ship and range and appears on the U. S. Cibola National Forest Map. Except for one or two established triangulation stations, however, no survey extends into the Sevilleta Grant, which includes most of the area of the Los Pinos Mountains.

FIGURE 1.—*Sketch map of New Mexico*
Showing location of the Los Pinos Mountains

ACKNOWLEDGMENTS

The study of the Los Pinos Mountains was made possible by a research grant from Northwestern University. Acknowledgments are gratefully made for the iterest and help given by all members of the Department of Geology. Special thanks are due C. E. Needham, then President of the New Mexico School of Mines and Director of the State Bureau of Mines and Mineral Resources,[1] at whose invitation the New Mexico work was undertaken, and who gave generously of his time to guide the party in reconnaissance over the area. His previous recognition of the character of the thrust faulting along the east side of the range and his intimate knowledge of the regional geology aided greatly in the present studies. Appreciation is expressed for use of the school library and to members of the New Mexico School of Mines staff for the many courtesies extended during the summer. R. E. Miller, on whose property

[1] Now Senior Mineral Economist, U. S. Bureau of Mines.

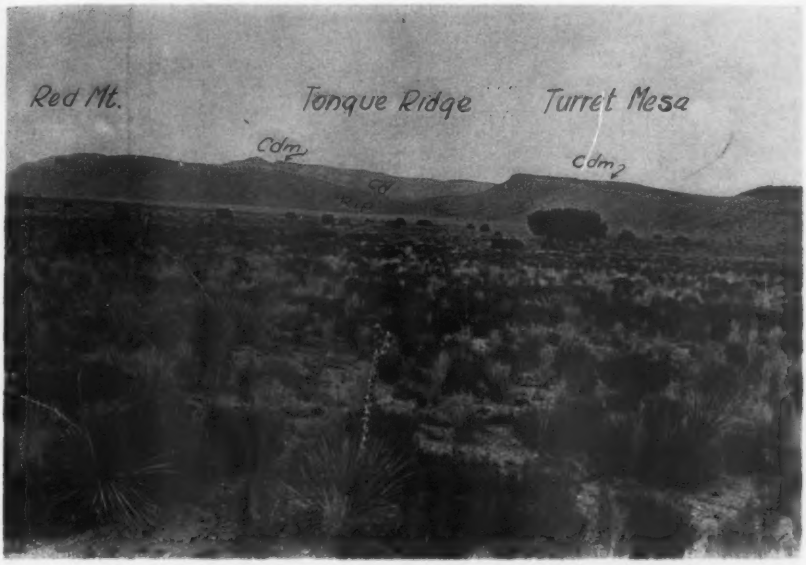


FIGURE 1. CUESTAS OF PENNSYLVANIAN LIMESTONE
In southern section of the Los Pinos Mountains. Foreground, Tio Bartolo pediment. Left background, Red Mountain (Los Pinos granite); center background, Tongue Ridge (Derry and Des Moines series); right background, Turret Mesa (Derry and Des Moines series).

FIGURE 2. VIEW LOOKING NORTH FROM WHITE FACE PEAK TOWARD MANZANO MOUNTAINS
Left center, Tio Bartolo pediment; center ridge formed by upturned Pennsylvanian strata along major thrust (Montosa); right foreground, valley in Blue Spring schist.

CUESTAS AND FAULTS

FIGURE 1. VIEW LOOKING EAST FROM SURFACE OF TIO BARTOLO PEDIMENT TOWARD STEEP WESTERN ESCARPMENT OF LOS PINOS GRANITE

FIGURE 2. BED REPRESENTATIVE OF NODULAR LIMESTONE TYPE
Showing characteristic weathered surface.

PEDIMENT AND NODULAR LIMESTONE

the party camped, and R. L. Parker, whose private roads were constantly used, were especially cordial and helpful with their knowledge of the region. The writers were assisted in the field by four graduate students from Northwestern University—Hugh E. Garrison, James J. Norton, Mortimer H. Staatz, and Ralph H. Wilpolt. Special acknowledgments are due the last three for their contributions to the detailed study of the fauna and lithology of the rocks of the area.

PHYSIOGRAPHY

GENERAL STATEMENT

Although the Sandia, Manzano, and Los Pinos mountains appear as distinct topographic units, their common history is revealed by the similarity in the geologic structure and physiography. Structurally they are linked with the Southern Rockies but physiographically they belong more to the mountains of the Basin and Range Province.

The Sandia, Manzano, and Los Pinos mountains are characterized by their bold, steep western front rising 2000 feet or more above the pediments of the Rio Grande Valley. Eastward the elevations gradually decline to the level of the Estancia Plain. In the Los Pinos Mountains, the most rugged topography and highest peaks are in the granite areas which form the western border. Here five peaks exceed an elevation of 7000 feet; of these Red Mountain is the highest by approximately 200 feet.

The present physiographic aspect of the Los Pinos Mountains must approximate that which prevailed in the Manzano Mountains before erosion removed so much of the Paleozoic cover. In the western part and extending the full length of each range is exposed a great core of pre-Cambrian rocks, which at one time were buried beneath late Paleozoic sediments. Subsequent to the uplift of the moutains, erosion of the Paleozoic strata exposed the pre-Cambrian rocks and developed a series of cuestas dipping southward and eastward from this section of highest elevation. In the Manzano Mountains, erosion is so far advanced that the cuesta development is no longer prominent in the west but is observed in the extreme eastern slopes of the mountains. In the Los Pinos, the cuestas are characteristic, particularly in the southern part of the range (Pl. 2, fig. 1).

A prominent ridge parallels the eastern border of the mountains and extends in a north-south direction with slight sinuosity. This ridge extends some distance into the southern end of the Manzanos beyond which it loses its prominence. In the Los Pinos, this ridge forms one of the most important structural as well as topographic features, since it consists of overturned beds of late Paleozoic strata along major thrust faults (Pl. 2, fig. 2).

The western face of the mountains is interpreted as a normal fault line scarp. Much of the abruptness which marks the mountain front, however, is due to several well-developed pediments in the Rio Grande Valley. Of these gently sloping surfaces the highest (Tio Bartolo) in this district abuts directly against the mountain face[2].

[2] For a description of the pediments and their development, the reader is referred to Denny (1941).

STREAM PATTERN

In general, the stream pattern is somewhat radial. The streams rise in the higher portions of the pre-Cambrian core and extend outward in all directions. Certain streams, however, have been influenced by the underlying structure. Along the western edge of the range at Turret Mesa, a stream follows the contact between granite and Pennsylvanian sediments and then turns abruptly westward to empty upon the Tio Bartolo pediment. North of Turret Mesa, most of the drainage is westward across the pre-Cambrian granite, rhyolite, and quartzite, but tributary streams have developed along the strike of the rocks and in many instances along schist zones. Within the igneous rocks the stream pattern is dendritic, and a topography characteristic of early maturity has been developed. The streams have advanced headward to the eastern limits of the White Ridge quartzite where thrust faulting has raised such rocks above the schists to the east. In the zone of Blue Springs schist, the topography is decidedly more subdued, and drainage is northward to Arroyo Abo in the north end of the range, eastward in the central section of the range, and southward in the area between Mountains Paloma and Montosa.

The few easterly flowing streams that drain the pre-Cambrian section flow in narrow gaps directly across the ridge developed by the thrust faulting. These abnormal courses represent drainage patterns established immediately after, or prior to, the elevation of the present mountains. This belief is based upon the following arguments:

(1) If the southward- and eastward-dipping Pennsylvanian cuestas be extended over the mountains beyond their present boundaries, they would meet over the present boundaries, they would meet over the present highest section of the range between Red Mountain and White Face Peak. This is the center from which the present radial drainage originates and must have been also the highest part of the range after the elevation of the mountains. Streams flowing eastward from the highest section cross a lowland of Blue Springs schist before entering the gaps across the scarps of the thrust faults and the higher ground to the east. Such stream courses must represent a pattern of superposed drainage established immediately after the mountain uplift or conceivably even before the elevation.

(2) Near Indian Knob (east side of the Range, locality D22) approximately 200 feet above the floor of the present eastward-draining streams are the dissected remains of an alluvial fan. Although the fan is not cemented, its elevated position, the fact that it is being dissected by the present streams, and the presence in the debris of pre-Cambrian rocks derived from the extreme western edge of the mountains indicate that it was not constructed by the present streams. Nevertheless, the material within the fan indicates that it was built by some ancestral stream flowing eastward from the western side of the mountains and from the region of present highest elevation. The present stream flows eastward, but its headwaters are restricted to the eastern part of the mountains. The stream which carried the debris to the fan must, therefore, represent an ancestral eastward drainage developed immediately after the Laramide uplift but whose course has been changed by subsequent events.

If the present drainage represents largely a pattern developed at the time of the mountain elevation, it should bear upon the problem of the late Tertiary course of the

Rio Grande. Denny (1940, p. 96–98) states that sediments believed to have been deposited by the Rio Grande during Pliocene time occur in Arroyo Abo not far west of the northern limit of the Los Pinos Mountains. Upon this and other similar evidence, he concludes that the river did not flow into the playa of the Socorro basin but flowed southeastward over the site of the Los Pinos Mountins. The indirect evidence from the drainage pattern in the Los Pinos Mountains, however, suggests that the river could not have flowed over the site of the present mountains for the following reasons:

(1) The dissected fan (mentioned above) of pre-Recent origin indicates that streams drained eastward from the pre-Cambrian area of the Los Pinos Mountains.

(2) The drainage pattern radiating from the present pre-Cambrian section of the range must have been established following the initial uplift of the range which, as will be demonstrated, preceded middle Pliocene time.

(3) In the granite and rhyolite areas on the western flanks of the mountains are two westward-draining valleys (Stadium Valley and another 1½ miles north) containing flats whose width exceeds a quarter of a mile. These valleys, in the mature stage of erosion, are unique among the youthful ones characteristic of this section of the mountains. Filling of the broad valleys by the streams occupying them at present appears unreasonable since the streams are distinctly unadjusted to their valleys and the watershed of the present streams. Rather, these valleys appear to be the former headwaters of westward-draining streams which aggraded their valleys during the epochs of Tertiary alluviation described by Denny (1940). The course of the ancestral Rio Grande through this section is still, therefore, in doubt, and more data bearing on this problem are required to plot precisely the course of the old channel.

PRE-CAMBRIAN

GENERAL LITHOLOGIC FEATURES

The pre-Cambrian core, which forms the boldest topographic feature of the Los Pinos Mountains, consists of a sequence of quartzites, siltstones, rhyolite flows, and basic schists intruded by pre-Cambrian granite. These formations have been divided into five mappable units, easily recognizable in the several traverses made across the range (Pl. 4). These are the Sais quartzite, oldest rocks in the area; Blue Springs schist, originally composed of shales and siltstones; White Ridge quartzite, a thick series of quartzose beds containing many gradations into argillaceous silts; Sevilleta rhyolite, surface flows which approximate 4500 feet in thickness; and the Los Pinos and Priest facies of granite. Numerous basic sills and flows, now largely altered to hornblende and chlorite schists, are intercalated with the sediments and rhyolites. Pegmatite and aplite dikes and numerous quartz veins cut all the pre-Cambrian formations and represent a late phase of the granite intrusion.

SAIS QUARTZITE

General statement.—The oldest pre-Cambrian sediments, the Sais quartzite is exposed on the up-thrown side of a thrust fault, in a belt extending along the east flank of the Los Pinos Range from Abo Pass southward for approximately 5 miles.

(The name is taken from the Santa Fe railway station of Sais near Abo Pass). North of the pass and also at the southern end of the quartzite outcrop, the width of the belt averages 1000 feet, but in the central part it is less than 500 feet wide. The rock varies from light to dark gray, with greenish and nearly white facies in a few outcrops. Its grain size is rarely more than 1 millimeter in diameter, and in most outcrops the grains cannot be distinguished megascopically. Massive quartzose beds 3 to 5 feet thick alternate with thinner-bedded zones, commonly sericitic, indicating argillaceous beds within the original sandstone. At the extreme northern end of the Sais quartzite outcrop, where it is intruded by the Priest granite, muscovite, biotite, feldspar, and epidote are recognized in hand specimens.

The east boundary of the Sais quartzite lies against the easternmost (Montosa) thrust fault. A brecciated zone in the quartzite is thoroughly silicified, ranges from 30 to 50 feet in width, and forms a prominent ridge along most of the outcrop. It marks the upthrown side of the fault with pre-Cambrian quartzite resting against Pennsylvanian limestone.

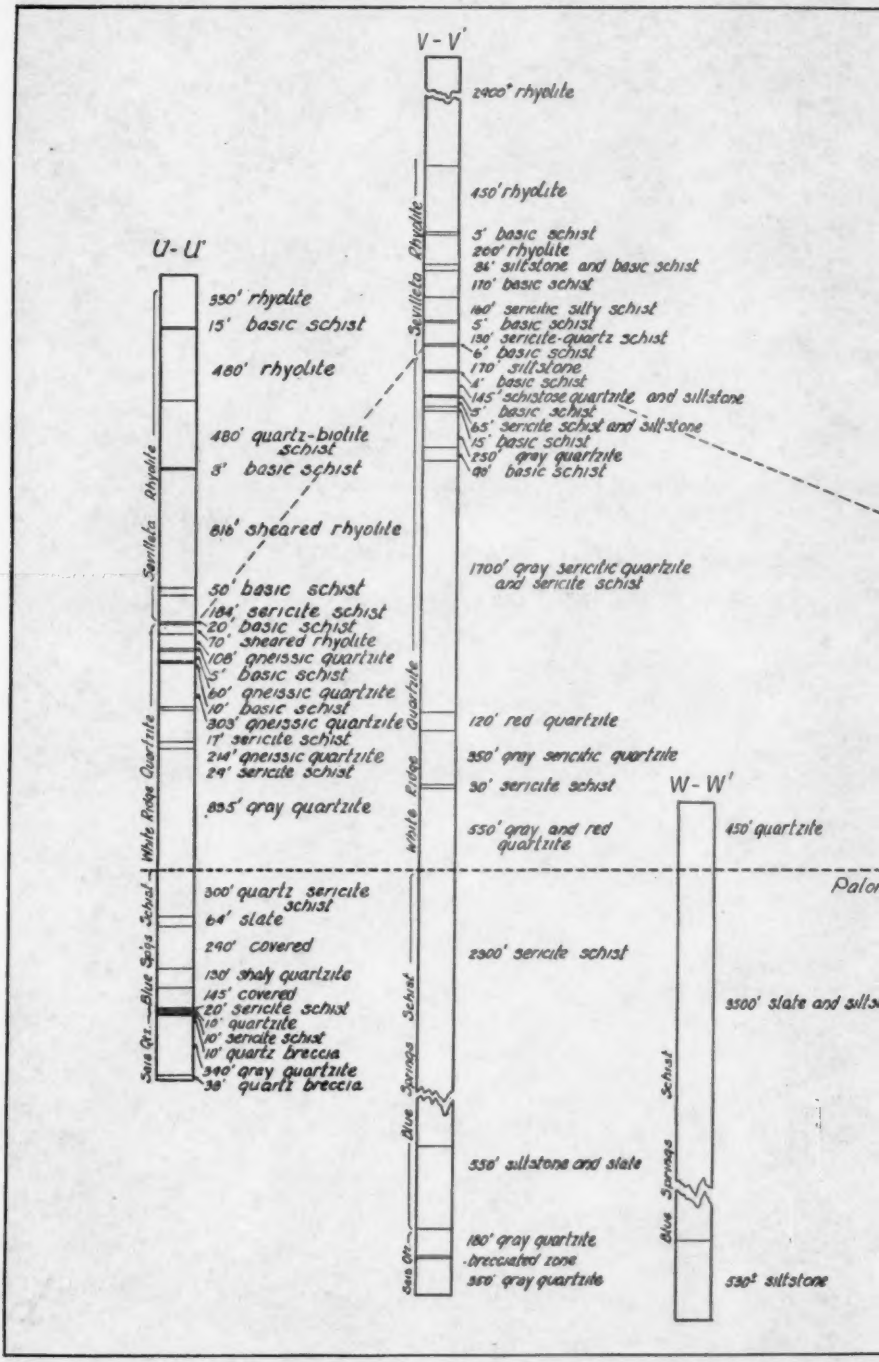
Excellent exposures of the Sais quartzite are in the quarries of the Atchison, Topeka, and Santa Fe Railroad near Abo Pass. The highly sheared quartzite crumbles readily under the blow of a hammer and has been quarried almost to the Pennsylvanian limestone on the downthrown side of the thrust. Bedding surfaces several hundred feet in length along the quarry east wall show well-developed slickensides and dip westward 55°, approximately parallel to the direction of the main thrust.

The greatest thickness of the Sais quartzite was measured at Abo Pass—approximately 600 feet. The exposed thickness south of Highway 60 is less. There is no evidence to suggest that the beds are basal, and since they are exposed in faulted relationship against the Pennsylvanian limestone the above figure may represent only a small part of the actual thickness.

The quartzite continues northward N. 20° E. beyond Abo Pass into the Manzano Mountains. At the southern end of the belt, in the north-central part of the Los Pinos Range, the beds are truncated by the Montosa thrust fault. In general the formation strikes N. 17° E. and dips westward at angles which average 52° but range locally between 25° and 70°. Near the top of the quartzite formation, the beds become increasingly sericitic, and no sharp boundaries can be drawn between this and the overlying Blue Springs schist formation.

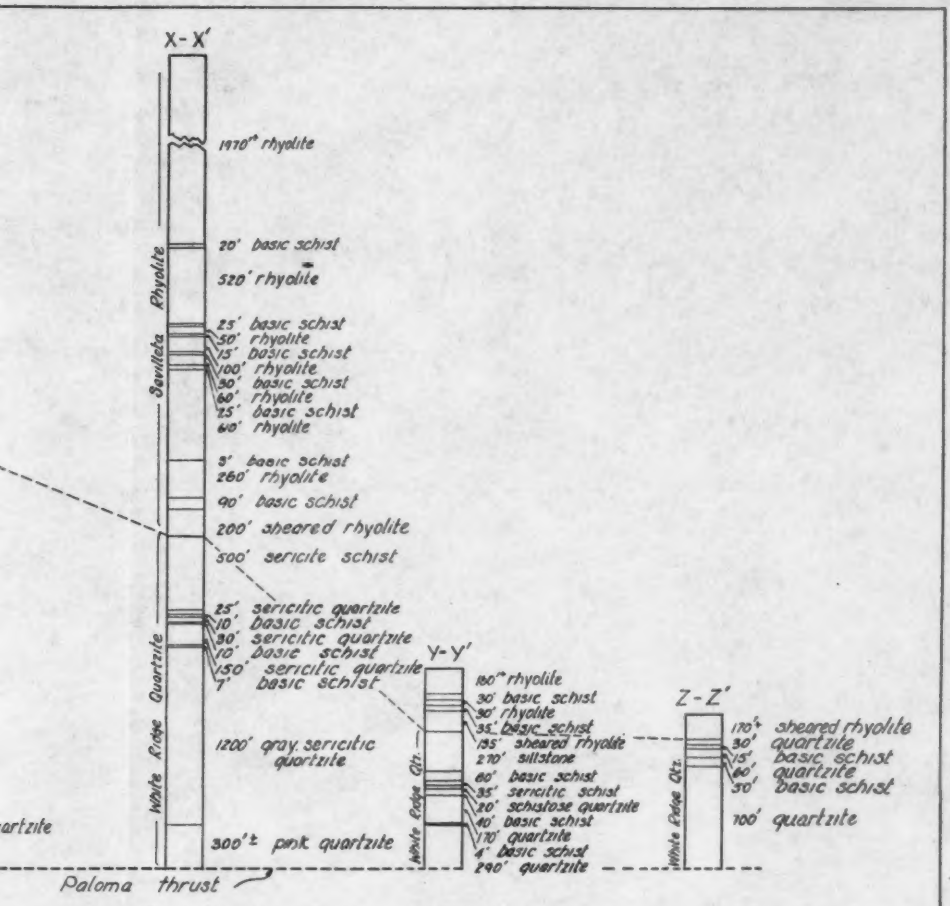
Lithology.–Under the microscope the quartzite shows a wide range in grain size, from .01 to .105 millimeter, due apparently to the opposite effects of granulation and recrystallization. Near the Montosa thrust, the shattering has been intense. Mortar structure is developed with remnants of larger grains embedded in finely granulated quartz. Large grains are formed at the expense of smaller ones by recrystallization. As the grains enlarge, they tend to become ellipsoidal with irregular or serrated edges. Such suturing and strain shadows are prominent in all specimens examined.

Sericite occurs as small fibrous grains showing well-developed orientation parallel with the long diameters of the ellipsoidal quartz. In the more impure beds the mica forms a felty matrix surrounding the larger, recrystallized quartz grains. Truman



STRATIGRAPHIC SECTIONS O

U-U′ section north end of the range along the south side of Highway 60. V-V′ section X-X′ section across range west of Sierra Montosa. Y-Y′ and Z-Z′ sections southwest of Sier



CTIONS OF PRE-CAMBRIAN ROCKS

-V' section across the range through White Face Peak. W-W' section north of Sierra Montosa.
vest of Sierra Montosa.

(1912, p. 306) suggests that under differential pressure the process of alteration seems to favor the production of flaky minerals, and that such minerals are not necessarily related to any particular bed but might cut across bedding in quartzites. In the Sais quartzite the sericite formed by recrystallization appears to be directly related to bedding, suggesting that the original sandstones varied considerably in purity. This is illustrated in Table 1, which shows the varying amounts of sericite

TABLE 1.—*Mineralogy of beds away from Montosa fault*
After Staatz (1942, p. 30).

	Horizontal distance in feet from the fault						
	0	5	38	103	160	265	482
Quartz	96%	88%	99%	93%	60%	90%	98%
Sericite	4	12	1	7	39	10	2
Magnetite	tr.	tr.	tr.	tr.	1	tr.	—
Zircon	tr.	tr.	tr.	tr.	—	—	—
Epidote	tr.	tr.	—	—	tr.	—	—
Apatite	—	—	—	—	—	tr.	tr.

in beds along a section away from the Montosa fault, at right angles to the strike of the beds. Since the amount of sericite does not depend on nearness to the fault, the original composition rather than dynamic action appears to be the determining factor in its formation.

Magnetite occurs in irregular detrital grains. A few larger euhedral grains suggest recrystallization. Zircon and apatite are widely scattered and are always rounded. Epidote and calcite are recognized but in extremely small amounts.

Thermal metamorphism.—In most parts of the Sais quartzite dynamic effects of the Montosa thrusting are predominant, but, at the northern end of the outcrop, where the quartzite is intruded by the Priest granite, thermal metamorphism is prominent. Here juices from the granite penetrated the sedimentary strata, and new minerals such as muscovite, microcline, and orthoclase form nearly 50 per cent of the altered zone. The thermal effects decrease away from the granite through a zone approximately 500 feet wide.

Muscovite occurs in poikilitic grains and forms 20 per cent of the rock nearest the granite. Microcline is next most abundant and forms 15 per cent of the rock near the granite. Orthoclase forms about 10 per cent of the altered quartzite and is widespread in contrast to the microcline and muscovite, both of which decrease rapidly away from the igneous contact. Biotite appears as an early product of recrystallization and shows less direct relationship to the granite. It ranges in amount from 1 to 10 per cent.

Secondary quartz occurs as large irregular grains. Commonly it surrounds the muscovite in clear rims. The quartz decreases in amount away from the granite and in the outer zone appears only in fine, hairlike stringers. Epidote, usually an alteration product of the biotite, is prominent in a few places.

BLUE SPRINGS SCHIST

General statement.—Under the formational name of Blue Springs schist is grouped a thick series of siltstones, slates, and sericitic schists, which are parallel with the enclosing formations and appear to rest conformably upon the Sais quartzite and below the White Ridge quartzite. (Blue Springs is located north of Highway 60 at the western flank of the Los Pinos Mountains and is a large seepage area where water is issuing from a schist herein called the Blue Springs schist.) Thin quartzose silt beds are commonly intercalated with the slates and siltstones, all of which grade laterally into one of the other facies along, as well as across, the strike. Thermal and dynamic metamorphic effects, such as the development of *Knotenschiefer* and sericite schist zones, are much more intense in some beds than others. Such micaceous zones served as plastic media over which the more massive quartzite beds were sheared in up-dip movements, and many small thrusts developed parallel to the general direction of the Montosa and Paloma fault zones. A dense slaty bed observed along one traverse may be represented a mile away by white, sericitic schist, due to locally more intense dynamic action. Gradational zones along the strike connect the two facies.

The belt of the Blue Springs schist formation extends from Abo Pass southward for 10 miles. For over half of this distance (from the north) it is bounded on the east by the Sais quartzite. Farther south the eastern boundary is formed by the Montosa thrust fault with Pennsylvanian limestone on the downthrown side. On the west the White Ridge quartzite is faulted against the schist by the Paloma thrust. The southern continuation of the pre-Cambrian sediments is covered by the limestone cuestas of the Pennsylvanian. Many variations in attitude occur throughout the schist, but an average strike of N. 20° E. and dips of 40°–60° W. are in accord with the regional pre-Cambrian structure.

The schist belt averages 500 feet in width north of Highway 60. Near the highway the outcrop widens and throughout the southern two-thirds of its length maintains a width of approximately a mile. The narrowness of the belt at the north is due to differential movement along the Montosa fault, which truncates the schist and brings up the White Ridge quartzite with a greater throw than in the southern part of the area.

The exposed thickness of the Blue Springs schist ranges from about 300 feet, between Abo Pass and Highway 60, to nearly 4000 feet in the vicinity of Sierra Montosa. Massive and brittle beds of red and gray slates and siltstones characterize the basal parts of the formation. The central parts are largely green, sericitic schists in which some zones are prominently contorted and crenulated. The schistose beds are intercalated with more massive slates and arenaceous siltstones. Many of the beds are spotted with biotite and blebs of granulated white quartz. Near the top of the formation there are beds of dense, red and gray, arenaceous slates, which become increasingly schistose as the overlying White Ridge quartzite is approached.

Lithology.—In general all rocks of the Blue Springs formation show effects of dynamic metamorphism. In some of the extremely fine siltstones little alteration other than compaction is apparent; in others small sericite flakes give a silvery sheen to fresh surfaces. So fine-grained is most of the formation that only the recrystallized

minerals (quartz, sericite, biotite, chlorite, and garnet) are recognizable. Quartz, however, is predominant in the siltstones and shales and ranges in size from .02 to 1.0 millimeter.

Under the microscope the spotted schists show a fine-grained matrix averaging 75 per cent quartz, 18 per cent sericite, and 1 or 2 per cent chlorite. Other constituents of the ground-mass are apatite, zircon, magnetite, and tourmaline. The first three appear detrital. Tourmaline occurs in long prismatic needles which by their fineness suggest late development due to effects of the granite. In some beds porphyroblasts of biotite forms as much as 10 per cent of the *Knotenschiefer*. They are euhedral) commonly poikilitic, and average 6 millimeters in diameter. In a few zones garnet prophyroblasts are abundant. Their relationship to chlorite is suggested by the conspicuous absence of this mineral in beds containing the garnets.

Thermal metamorphism.—North of Abo Pass where the Blue Springs formation approaches the Priest granite, apparently due to the force of intrusion the northeasterly strike of the beds gradually turns westward as the contact is approached. Here about 300 feet of Sais quartzite separates the schists from the granite. Thermal effects of the intrusion were studied by Staatz and Norton (1942, p. 44) in a 3000-foot section of schist. The specimens were selected at irregular intervals where changes occurred in the character of the outcrop. The results are given in Table 2. Thin sections and field studies suggest that the original composition of the beds rather than nearness to the granite is most important in determining the character of the metamorphism. Differences in porosity and heat conduction undoubtedly were factors in selective metamorphism of certain beds over others. Thus, the presence of tourmaline associated with shear zones may be explained by access of magmatic solutions to such zones.

Originally the schists were impure siltstones composed largely of quartz. The grains show some recrystallization but for the most part the quartz is in very fine, rounded to subangular grains. Feldspars, if ever present in the schist nearest the granite, have disappeared and are first recognized in beds 1750 feet from the contact. Biotite and chlorite occur throughout the section and show no apparent relationship to the intrusive contact. Sericite is most abundant in zones of shearing. It occurs in fibrous grains and shows well-developed parallel orientation.

Muscovite is abundant as irregular tabular grains lacking orientation in the zone near the granite where solutions appear to have brought in potassa and alumina. Although some of this material may have been derived from original feldspars, in none of the unaltered siltstones is there sufficient potassa and alumina to account for the abundance of muscovite in the contact zone.

After muscovite, sillimanite occurring as fibrous, hairlike needles is the most distinctive marker mineral. It appears in a narrow zone overlapping the muscovite between 500 and 1000 feet from the granite. On the outer border of the sillimanite zone is a 3-foot belt containing andalusite. It is a late mineral occurring in large, irregular, commonly elongate, poikilitic grains which stand out as resistant knobs on weathered surfaces.

Garnets ranging from 0.5 to 1.5 millimeters in diameter are widely scattered throughout the section, suggesting recrystallization of original material. Near the

TABLE 2.—*Mineral composition of the Blue Springs schist*

Minerals present	Approximate distance (in feet) from granite contact																
	80	100	500	850	1000	1100	1300	1500	1550	1600	1750	1900	1960	2220	2730	2770	2820
Quartz	50%	61%	52%	65%	84%	2%	40%	80%	86%	55%	74%	88%	72%	76%	93%	88%	85%
Feldspar											15		8	6	tr.		
Muscovite	42	18	40	20									<1				<1
Sericite	tr.	tr.	tr.	tr.	2		55	2	<1	20	4	8	1		5	3	
Biotite	7	15	4	8	10		<1	12	10	18	2	3	16	<1	1		
Chlorite	1	tr.	2	2			2	7	2	3						2	tr.
Garnet	1	1	<1					tr.	1	2	<1				<1	<1	tr.
Sillimanite			tr.	3	1												
Andalusite					4												
Epidote					tr.						3		<1	17			
Tourmaline	<1	<1					tr.	tr.	tr.					tr.		1	12
Zircon						tr.	tr.		tr.		tr.				tr.		tr.
Apatite	tr.							tr.				tr.		tr.	tr.	tr.	
Magnetite	<1	<1	1	<1	tr.					2	2	1	3	tr.	1	tr.	3
Hematite								1									tr.
Black, opaque mineral		4					2		<1								
Calcite						71											
Clinozoisite						25											

tr = trace
<1% = a little less than 1%

granite contact many of the crystals show dark centers which may represent rapid initial crystallization. Later slower growth would permit a more complere replacement and form the clearer borders of the prophyroblasts. The garnets are larger, poikilitic, and more irregular in outline farther from the granite contact.

Tournaline is most abundant on the outer edge of the thermally metamorphosed zone, but traces are found in several places throughout the aureole. Epidote is a late mineral, and its association around small pores in the schists, where solutions reacted on feldspars, suggests hydrothermal action.

A rude zoning is suggested by the distribution of minerals shown in Table 2. The first zone is characterized by abundant muscovite in large, irregular, poikilitic grains. The second zone overlaps the first and contains fine, hairlike needles of sillimanite. A third zone contains no distinctive minerals and is followed by a zone containing small, round grains of epidote. This zoning is not clearly defined, and from field observation the original composition of the beds appears to have been more important than nearness to the igneous contact in determining the character of the thermal effects.

WHITE RIDGE QUARTZITE

General statement.—The high, eastern ridge crests in the northern half of the Los Pinos Range are formed by westward-dipping beds of the White Ridge quartzite. (The formation is named after White Ridge, a prominent ridge on the eastern side of the pre-Cambrian section of the Los Pinos Mountains.) The outcrop maintains a width of a mile for 5 miles south of Highway 60, then narrows to less than half a mile and continues southward for another 5 miles. North of Highway 60, the belt is only 500 feet wide due to erosion along the western slopes and encroachment of the Tertiary sediments. The east boundary of the quartzite coincides, along the northern two-thirds of the outcrop, with the trace of the Paloma thrust fault. This is marked by a more or less continuous zone of silicified fault breccia in the quartzite. Southward from Highway 60, the quartzite is overlain by the Sevilleta rhyolite flows.

The White Ridge fomation near the base is composed of massive quartzite beds 2 to 7 feet thick. These vary from white to light pink, tan, and red. Impure shaly beds occur throughout the formation and become prominent near the top. Here thin beds of gray quartzite 1–2 feet thick alternate with schistose zones of gray and white sericitic schist.

Hematite becomes an important coloring agent near the top of the formation where the beds vary from light pink to red. Recrystallization and shearing have so altered parts of the impure quartzite beds that in places they are easily confused with sericitic schists formed by shearing in the overlying rhyolite flows.

In the central part of the belt the White Ridge quartzite ranges from 3000 to 3700 feet thick. Near Sierra Montosa it thins to 900 feet, due to the absence of the upper part of the formation. This presumably was eroded before the extrusion of the rhyolite flows.

The beds of the quartzite formation maintain a more constant strike direction in accordance with the regional structures (N. 20° E.) than do the more highly distorted

schists. Dips range from 32° W. to 60° and 70° where massive quartzite beds have been tilted and moved upward over the softer and more plastic schistose zones.

Lithology.—The White Ridge formation is dominantly a quartzite. The grain size ranges from extremely fine to very coarse sand. Sufficient sericite is commonly present to give a silky luster to fresh specimens, and biotite in very fine flakes occurs in a few zones.

Under the microscope the dynamic effects of granulation and recrystallization are prominent, especially as the Paloma thrust fault is approached. The development of stress minerals is favored in contrast to the minor effects of thermal metamorphism. Quartz grains show strain shadows and sutured contacts. Complete recrystallization near the fault has resulted in elongate grains with the ratio of length to width as high as 10 to 1. Farther from the shearing zones granulation is more important.

Sericite, biotite, and hematite are developed in the less pure beds. Scattered grains of detrital apatite, zircon, and tourmaline (probably not detrital) occur locally but only in traces. The more schistose beds contain as much as 40 per cent sericite. It occurs in long, fibrous grains forming mats around isolated quartz grains.

Border facies.—The White Ridge quartzite is overlain by approximately 4500 feet of rhyolite flows. Sill-like intrusions of rhyolite cut the upper 400 feet of the sedimentary formation. During the folding and thrusting from the west this zone was much sheared, and the resulting granulation and recrystallization have so altered the rocks that distinction in the field between rhyolite and quartzite is difficult. Augen and flaser structures occur side by side with porphyroblastic minerals. Sheared sericitic quartzite contains porphyroblasts of orthoclase ranging from 1 to 3 millimeters in diameter. Sheared rhyolite shows remnants of feldspar and quartz phenocrysts in a sericitic groundmass. Epidote is abundant as a late mineral after feldspar and forms as much as 40 per cent of some specimens. Calcite is also widely scattered throughout the intermediate zone but rarely makes up more than 1 per cent of the rock.

SEVILLETA RHYOLITE

General statement.—Disconformably upon the westward-dipping White Ridge quartzite is a remarkably thick series of acid flows. These have been named the Sevilleta rhyolite after the old Sevilleta land grant within the bounds of which the rhyolites occur. Careful measurements north of Los Pinos Arroyo give a thickness of 4500 feet; and, since the flows disappear beneath the pediment cover to the west and show no evidence of close folding or reversals in dip, the actual thickness is undoubtedly greater than the exposed section.

The rhyolite forms a belt that extends south and southeast from Highway 60 across the range for more than 5 miles to the place where it disappears beneath the southward-dipping Pennsylvanian limestone. The outcrop is widest near the central part of the range, where it averages 1½ miles, but in no place is it less than half a mile wide. The strike of the flows conforms to the regional trends of N. 20° E., and westward dips range from 30° to 80°. In general the dips of the flows appear slightly steeper than those of the underlying sediments.

The base of the formation contains about 500 feet of more or less compact, sericitic rhyolite which grades downward into the highly sheared and recrystallized zone of the White Ridge quartzite. The schistose rhyolite varies from light buff to reddish brown. Its groundmass is extremely fine-grained and compact and in nearly every outcrop exhibits a silky luster due to the abundance of sericite. Where no phenocrysts occur the schistose rhyolite is distinguished with difficulty from the underlying sericitic quartzite. Other flows in this part of the rhyolite are thickly dotted with phenocrysts of pink orthoclase which range from 1 to 15 millimeters in length.

This basal schistose facies grades upward into progressively less metamorphosed rhyolite that varies from dark red to black. Phenocrysts of orthoclase and quartz are abundant in a black aphanitic groundmass. In a few places a light silvery sheen indicates the development of sericite, but for the most part the upper flows show only slight alteration. In this upper part of the section the flow character is readily apparent from the abundance of flow lines and chilled borders marking the tops of the flows. In the lower zones contacts between the flows are masked by shearing, although flow lines are recognizable throughout the entire section.

Lithology.—Megascopically two distinct facies of rhyolite are recognized—the light to buff schistose rock at the base, and the upper flows of dense, dark-red to black rhyolite. Under the microscope this difference appears due entirely to the intensity of shearing and development of a schistose groundmass.

The groundmass is crystalline; grain size averages less than half a millimeter in diameter. Much of it shows the patchy pattern characterisric of devitrified glass. In the highly sheared flows the grain size increases slightly by recrystallization. Sericite is abundant and masks most of the other constituents. Biotite and extremely small grains of iron oxide and calcite usually constitute less than 2 per cent. Some of the larger phenocrysts show parallel orientation due to flowage. Commonly their edges are granulated by later shearing, and they stand out as resistant augen around which flow and shear have bent the mica flakes.

The dark, less-metamorphosed rhyolite has a fine-grained groundmass composed chiefly of quartz and feldspar. Quartz is dominant, and orthoclase is the most abundant feldspar. Small amount of biotite, sericite, epidote, magnetite, apatite, calcite, garnet, and sphene are present. Of these magnetite is the most abundant; it forms as much as 2 per cent of some of the sections. Phenocrysts average about 8 per cent of the rock and are of quartz, orthoclase, albite, and microcline. As in the groundmass, orthoclase is the most abundant feldspar. The albite (Ab_{92} An_8) is close to oligoclase. Microcline is less common than either of the other two feldspars.

BASIC SCHISTS

General statement.—With the exception of the granites, all the pre-Cambrian formations contain sill-like intrusions, dikes, and interbedded flows of basic igneous rock, now largely altered to hornblende and chlorite schist. These basic schist zones range in thickness from 1 foot to 170 feet. In the majority of outcrops, they appear parallel to the bedding, but in a few places transgressive relationships are clearly exposed. Recrystallization and shearing have, for the most part, obscured all traces of primary igneous features, but in several outcrops vesicular and amygda-

loidal textures suggest tops of flows. At three separate horizons the schists show definite outlines of ellipsoidal structures with amgydules arranged radially around the periphery of the pillows. The ellipsoids range in diameter from a few inches to a foot in length. In the absence of such structures the basic schists were mapped as sill-like intrusions, but many such zones may actually be surface flows.

Lithology.—Where exposed, the basic zones are dark green and are composed chiefly of acicular hornblendelike crystals. Chlorite and lens-shaped prophyroblasts of pink feldspar averaging from 2 to 4 millimeters in length are present in a few specimens. The degree of schistosity varies with the zones, and a few zones lack distinctive schistosity and have well-developed diabasic texture.

The amphibole needles are pargasite, a low-soda, high-aluminous member of the pargasite-hornblende series. (Optically +, dispersion $\rho > V$, and pleochroism, X = straw yellow, Y = emerald green, and Z = greenish yellow.) The needles are usually less than 1 millimeter long. They average about 34 per cent, but in some zones form as much as 50 per cent, of the schist.

Feldspar is the next most important constituent, averaging approximately 27 per cent. Most of it is untwinned and appears to be orthoclase, but its highly altered condition makes the determination difficult. A few outcrops have as much as 5 per cent of twinned feldspar. All the feldspar is much altered, and in some zones it is completely replaced by epidote.

Epidote makes up from 15 to 40 per cent of the schist. Quartz averages about 15 per cent. Both minerals, in addition to being well scattered throughout the rock, occur in small veins cutting the schist. Magnetite in irregular and euhedral grains is associated with the epidote. Sericite and chorite are present in small amounts as alterations of the feldspar and amphibole.

For the most part, the basic schists do not appear to have been sheared so intensely as the rhyolite and quartzite. Alteration appears to have been largely accomplished by hydrothermal solutions, and passageways for such solutions are now filled with epidote and quartz.

GRANITE—LOS PINOS FACIES

General statement.—The intrusion of granite with its associated pegmatite and aplite dikes and quartz veins is the last recorded event of the pre-Cambrian in this region. Since the granite constitutes such a major part of the mountains it has been called the Los Pinos granite. It forms a steep western escarpment for 7 miles along the central and southern parts of the range (Pl. 3, fig. 1). At the extreme southeast end, the outcrop fingers out into several low ridges separated by xenoliths of the Blue Springs schist formation. At the north the granite abuts against the Sevilleta rhyolite flows. The contact of the granite and flows extends from a point on the western flanks of the range, 4 miles south of Highway 60, irregularly southward for 6 miles. On the south and southeast sides the granite is overlain by Pennsylvanian sediments.

A large xenolith, probably a roof pendant, of schist and schistose quartzite forms an irregular outcrop in the granite, from near the center of the west boundary southward for 3 miles. It ranges in width from a few hundred feet to nearly half a mile.

The borders of the schistose inclusion are completely granitized, show abundant development of porphyroblasts, and at no place can any sharp boundary be drawn between the xenolith and the granite. The borders of the granite mass contain many small lens-shaped inclusions of schist and quartzite.

The central part of the schist xenolith, less metamorphosed by the granite juices and more susceptible to erosion, is now occupied by Stadium Valley, a large amphitheater-shaped hollow. South of this valley is Red Mountain, composed of granite. The east side of the mountain is formed by a xenolith of quartzite, about 2 by 1¼ miles in extent, showing a transitional zone between the sediment and intrusion in which every degree of gradation between quartzite and granite occurs.

At the extreme southern end of the granite outcrop, a number of schist beds are incorporated in the granite. Some zones were fairly resistant to penetration by juices and form lenses several hundred feet in length, completely surrounded by granite. Other areas of schist have been completely granitized. In still others the schist is commonly interlayered with small granite partings 1 or 2 inches wide. Many "knots" of gray, sericitic schist occur throughout the granite. These small xenoliths show a striking foliation that agrees in direction with the schistosity of the larger schist lenses. Dark minerals, largely biotite, are abundant in the granite zones surrounding the granitized schist. The field relations suggest that the granite intruded the older pre-Cambrian formations and in part—or wholly—assimilated or replaced them.

The tendency toward schistose structure is apparent in the most normal facies of the granite and is marked by parallel orientation of the dark minerals. The schistosity throughout the granite area, whether measured in the extremely schistose border zones, in the schistose lenses, or near the center of the granite outcrop, agrees roughly with the N. 20° E. trend of the sediments. In a few areas miarolitic cavities are extremely common in the more massive and less schistose facies of the granite.

Lithology.—The Los Pinos granite, in its least contaminated facies, is a medium-coarse-grained, pink rock composed largely of microcline, orthoclase, albite, and quartz. Biotite is the most prominent dark mineral, but, except where schist inclusions appear to have been more or less completely assimilated, it averages less than 2 or 3 per cent. Where the biotite increases in amount to as much as 7 per cent it is intimately related to the schist inclusions and adjacent formations. Magnetite is the only other dark mineral of any importance.

Quartz occurs in colorless and bluish grains rarely larger than a quarter of an inch in diameter; it averages as much as 48 per cent in most of the granite. Where there is an intimate mixing of schist and granite, the quartz content increases to 60 per cent.

Microcline and albite respectively are the most common feldspars. In some places the grains attain half an inch in length. Micrographic intergrowths of quartz and feldspar are abundant, and many such areas resemble typical vermicular myrmekite.

Accessory minerals other than biotite and magnetite are muscovite, apatite, garnet, and zircon. None of these is common, and they total less than 1 per cent of the granite.

The abundance of graphic intergrowths, while not a proof of replacement, is not unfavorable to such an interpretation (Gilluly, 1933, p. 72). The increase of the

amounts of quartz and biotite around the remnants of schist inclusions, the gradual disappearance of the schist inclusions by the development of porphyroblastic feldspar and quartz, and the wide granite-schist and granite-quartzite transition zones support the idea that much of the exposed granite originated in place by assimilation and replacement of the sediments. Furthermore, the central part of the granite outcrop shows the least evidence of any added material and suggests a core of intruded granite grading outward through a migmatitic facies into the host rock.

GRANITE—PRIEST FACIES

General statement.—Pre-Cambrian granite crops out in the Manzano Mountains with the same intrusive relationships to the pre-Cambrian sediments as the Los Pinos granite shows farther south. The two granites also are similar in composition and structure, but because of the distance separating the outcrops the granite of the Manzano Mountains was designated the Priest granite. (The Priest granite has been named from its occurrence at Priest Peak in the Manzano Mountains.) The two granites are separated by approximately 6 miles of the rhyolite, quartzites, and schist already described. One mile north of Abo Pass, the Priest granite forms the northern abutment of the belts of Sais quartzite and Blue Springs schist. The Montosa thrust limits the granite on the east, and the Tio Bartolo pediment encroaches on its western flank. The granite outcrop continues northward into the heart of the Manzano Mountains.

The Priest granite is a coarse-grained rock composed chiefly of pink feldspar, quartz, and biotite. In numerous places there are irregular areas of pegmatite with gradational borders into finer-grained granite. Feldspar crystals are commonly 3 inches long. The rock weathers readily to rounded knobby surfaces, and most slopes are covered with gruss grading downward into deeply weathered granite.

The granite contains many xenoliths of schist. These are scattered throughout the rock but increase both in size and number toward the contacts with the intruded rock. Such inclusions are believed to have been derived chiefly from the Blue Springs schist, which strikes into the granite from the south. Xenoliths of quartzite are less common. Both types of inclusions are more resistant than the granite and stand out above the erosion surface as extremely lumpy knobs.

In the border zone biotite is prominent, and the schist appears to have been partially assimilated and replaced by the granite. Such an interpretation is supported by: (1) the high biotite content of the schist and its scarcity in the granite where the schist inclusions seem least altered; (2) the conspicuous increase in the amount of biotite in the granite as the gradational schist contacts are approached; (3) weblike patterns of biotite outlining shadowy borders of almost completely assimilated or replaced schistose inclusions; (4) trailing out of schist xenoliths into the granite; (5) the lack of any homogeneity of schistose areas; (6) the development in the schist of porphyroblasts of quartz and feldspar, commonly more than 3 inches in diameter, in a fine-grained schistose groundmass.

Quartzite inclusions, in contrast to those of schist, show very little alteration other than recrystallization. The quartzite xenoliths range in size from lengths of a fraction of an inch up to 60 feet.

Lithology.—Under the microscope orthoclase, microcline, and albite are recognized, but the extremely weathered condition of the granite makes determination of much of the feldspar difficult. The total feldspar content averages from 60 to 65 per cent. Microcline is abundant and occurs in borders surrounding the granitized schist nodules. Albite (Ab_{92} An_8) makes up 50 per cent of the rock. All the feldspars show much saussuritization, kaolinization, and epidotization.

Quartz occurs as large irregular grains, ranging from 1 to 3 millimeters in diameter. It is later than, and commonly surrounds, the biotite. In many specimens it averages 35 per cent of the granite.

Biotite is the next most abundant mineral and varies greatly in amount according to the quantity and degree of assimilation of the schistose bodies. In favored areas around the granitized schist nodules it makes up 15 per cent of the rock but in areas of clearer granite it averages only 3 or 4 per cent. In most places, it shows alteration to chlorite and associated epidote. Apatite is widely scattered throughout the granite in small grains.

CORRELATION OF THE GRANITES

The Los Pinos and Priest granites are similar in color and general appearance. Both are light pink, medium-to coarse-grained, and form the high rugged topography of their respective ranges. Both intrude the same pre-Cambrian formations, and they are separated at the surface by about 6 miles of covered area.

The mineralogy of the two granites is strikingly alike. Both are composed chiefly of three feldspars (microcline, orthoclase, albite) and quartz. Biotite is the chief accessory mineral, and its amount increases toward the schist bodies. Despite this outward similarity there is wide variation in the percentage distribution of these minerals even within the same granite; hence, no reliance can be placed on mineral distribution as a criterion of recognition or distinction.

The chief differences between the two granite outcrops are: (1) the coarser grain of the Priest facies, (2) its consequent deeper surface weathering, (3) the greater abundance of small xenoliths in the Priest Peak area in comparison to the elongated zones of partially granitized schist and quartzite in the Los Pinos area, (4) the sharp boundaries and slight alteration of the quartzite inclusions (except recrystallization) in the Priest facies in contrast to the extremely gradual transitions from quartzite into granite in the border zones of the Los Pinos granite.

All of these differences could be explained by varying degrees of intensity in the contact effects of the intrusion. Border zones of both granites appear to have been formed in part at least by "a stewing of pre-existing rock material in liquids of magmatic and/or palingenic origin" (Barth, 1936, p. 839).

Lit-par-lit injection of granite juices into the adjoining sediments and schist inclusions, the transition of schist and quartzite into granite by the development of porphyroblasts of feldspar and quartz, and the increase in biotite content of the granite where inclusions appear to be most completely assimilated all appear to be the effects of a large batholithic invasion. It seems very likely that the Priest and Los Pinos facies are separate surface outcrops of granite that is continuous at depth. In the absence of definite evidence, the two outcrops have been described separately,

but nothing in the present study suggests that they are not part of a common, larger granite mass that underlies both the Los Pinos and Manzano ranges.

PEGMATITE AND APLITE DIKES

Border zones of the Los Pinos granite and the adjacent rhyolite, schist, and quartzite formations are cut by numerous pegmatite and aplite dikes. The pegmatites are similar texturally and mineralogically to the coarse-grained facies of the granite. They range in width from thin stringers of less than an inch to 30 feet. Aplite dikes are also characteristic of the border zones. They are less numerous than the pegmatite, especially in the neighboring sediments. Aplites and pegmatites are closely associated and show mutually intrusive relations.

QUARTZ AND QUARTZ-FELDSPAR DIKES

General statement.—A last phase of the pre-Cambrian igneous activity is shown by a series of quartz veins which cut all the pre-Cambrian formations. Because of their great abundance, widespread occurrence, and distinctive character they are discussed separately from the pegmatites, but all gradations exist from quartz veins to highly feldspathic pegmatites. Lateral continuity, however, between the quartz-feldspar veins and typical pegmatites is not common. The veins range in width from a fraction of an inch to 40 feet. They are so closely spaced on the northern crests of the Los Pinos range that they can be recognized from a distance of several miles. Although dikelike stringers are present, in general the veins parallel the bedding and schistosity. Along the strike they pinch and swell, commonly die out, or are dispersed in numerous small *lit-par-lit* stringers.

It is assumed that all the dikes and veins are derived from the same magma chamber. The relation of the vein-dikes to the pegmatites is established in a few outcrops where typical pegmatite grades into quartz veins. Many veins, composed only of quartz for hundreds of feet, are traceable along the strike through zones showing increasing amounts of feldspar until the composition appears identical with the pegmatites which characterize the border zones of the Los Pinos granite.

Lithology.—The veins are composed predominantly (over 95 per cent) of white milky quartz and salmon-colored microcline. The microcline is not well distributed but favors certain sides or parts of the vein. Commonly long tongues of microcline project into the quartz and constitute as much as 35 per cent of the total mineral matter in the microcline-rich veins. It is present in smaller amounts in approximately 40 per cent of all the veins studied. A few veins contain black tourmaline in long anhedral grains, ranging from extremely small nodules up to bladed prisms an inch in length. Such crystals are developed more or less transversely to the veins.

METAMORPHISM OF THE PRE-CAMBRIAN ROCKS

General statement.—The thick series of crystalline pre-Cambrian rocks of the Los Pinos Range have been subjected through a long period of time to numerous environmental changes, giving rise to several types of metamorphism, commonly superimposed one upon the other. Early regional metamorphism is partly obliterated in thermally metamorphosed aureoles around the granite intrusions. Different periods

of shearing during folding and thrust faulting have resulted in widespread dynamic metamorphism, which in many zones has completely destroyed the effects of earlier regional and thermal metamorphic changes.

Regional metamorphism.—All the pre-Cambrian sediments show the effects of an early regional metamorphism of low to moderate intensity, in the formation of quartzites, slates, and schists from sandstones, shales, and siltstones. The Sevilleta rhyolite, youngest member of the pre-Cambrian series, is the least affected; the chief change observed is the development of small amounts of sericite. This regional metamorphism took place after the extrusion of the rhyolite flows and before, or in part contemporaneous with, the formation of the thermal aureoles around the granites, since in these border zones the low-grade metamorphism has been obscured by the development of higher-temperature minerals.

In the discussion of the correlation of the granites it was suggested that the Priest and Los Pinos facies are outcrops of a large mass which is continuous at depth and which underlies large parts of the Manzano and Los Pinos ranges. If such a hypothesis be correct, so large a magma chamber, presumably underlying all the pre-Cambrian sediments, would be a reasonable source for the heat which caused the region-wide metamorphism, without the support of any pronounced diastrophic movements (Barrell, 1921, p. 1–19). Tilting of the sediments to the west may have been contemporaneous with the batholithic intrusion, but there is no evidence of intense folding in the region.

The formations affected by regional metamorphism are the Sais quartzite, Blue Springs schist, White Ridge quartzite, and Sevilleta rhyolite. The last is the most stable under high temperatures and consequently shows the least alteration. The chief effects on the rhyolite appear to be the sericitization of the feldspars.

The Sais and White Ridge formations were fairly pure quartz sandstones, and recrystallization was the chief process in the formation of the quartzites. In impure clayey beds, sericite schist developed, and sericite is sparsely scattered in very small flakes throughout some of the massive quartzite beds. The regional metamorphism is complicated and obscured by later dynamic metamorphism in the Sais quartzite and to a lesser extent in the White Ridge quartzite.

The Blue Springs formation is finer-grained and more argillaceous than the quartzites. New minerals were easily formed, and various types of schist and slate developed. A large area of *Knotenschiefer* crops out south of Highway 60. Such spotted schists are characteristic of low-grade metamorphic zones where incipient crystallization has just begun (Harker, 1932, p. 48–49). Biotite and garnet are the prominent new minerals. The mica forms poikilitic patches, 5–7 millimeters in diameter, in a fine-grained groundmass of quartz, sericite, and chlorite. Garnets are smaller and less abundant than the biotite. Sericite is present throughout the entire formation.

Thermal metamorphism.—Thermal metamorphism is pronounced in irregular aureoles around the two granite outcrops. If the regional metamorphism was caused chiefly by the presence of a large granite massif underlying the sediments, the contact zones may be considered as more intensive and localized alterations caused by the same igneous invasion.

New minerals in the Sais quartzite and Blue Springs schist have been formed by

several processes: (1) the addition from the granite magma of new material to the border zones; (2) recrystallization, by the aid of heat, of original material in the aureoles; and (3) hydrothermal solutions reacting with old minerals to form new ones. Muscovite is not found in the sediments outside the thermal aureoles, but it is abundant near the granite in both the quartzite and schist. Two other minerals in this category are microcline and secondary quartz. Near the granite secondary quartz is indicated by: (1) the bordering rims it forms around the poikilitic muscovite grains, (2) the fresh, clear appearance of the quartz, and (3) the irregular shape of the grains in contrast to the indigenous quartz grains.

In the Blue Springs formation a rude zoning of thermal minerals is evident in the contact aureole around the Priest granite, in spite of the fact that the varying composition of individual beds plays an important part in determining the kind of new minerals formed. Muscovite characterizes the innermost zone, followed by sillimanite, then a zone in which no minerals indicative of thermal metamorphism occur, and finally an outer zone of epidote and feldspar. Tourmaline occurs in the schists, commonly several miles from the granite contact, in amounts usually less than 1 per cent, but it ranges up to 12 per cent in a few beds.

Certain metasomatic changes in the quartzite were also effected by the granite intrusion. Biotite, judging from its irregular distribution, was probably formed largely from the material at hand, but muscovite, microcline, and possibly part of the secondary quartz appear to have been formed of material added by solutions carrying K_2O, Al_2O_3, and SiO_2. The nonthermally metamorphosed sediments do not contain sufficient amounts of K_2O and Al_2O_3 to account for the formation of 20 per cent muscovite, 15 per cent microcline, and 10 per cent orthoclase. The SiO_2 may have been derived from the quartzite or in part brought in from the granite.

Distinct zoning is not evident in the contact aureole of the Los Pinos granite, probably because the only formation in contact with the granite (except for the inclusions of schist and quartzite) is the Sevilleta rhyolite. The rhyolite contains approximately the same minerals as the granite, both rocks would be in equilibrium at high temperatures, and thermal metamorphism accordingly has had little effect on the rhyolite. Contacts between the large xenoliths of schist and quartzite with the granite are extremely gradational; at no place can the schist and quartzite be traced into the larger outcrops of their respective formations.

Dynamic metamorphism.—The effects of intense dynamic metamorphism are prominent in three zones: (1) in the Sais quartzite adjacent to the Montosa thrust fault; (2) in the White Ridge quartzite along the Paloma thrust fault; and (3) in all the layered formations along numerous planes of slippage caused by younger, more massive beds moving upward and over older, weaker beds, as in the intensely sheared transition zone between the Sevilleta rhyolite and the underlying White Ridge quartzite. Some of this movement was undoubtedly initiated during the original tilting of the beds. The most intensive shearing, however, was associated with thrust faulting, and it seems likely that widespread movements between beds may also have been recurrent at the time of the thrusting in post-Permian time.

The most important effects of the dynamic metamorphism are the development of sericite and the recrystallization of quartz. Along the Montosa thrust the sheared

quartzite averages about 10 per cent sericite, but in certain zones it forms as much as 20 per cent of the rock. Similar sericitic quartz schist zones are developed in the White Ridge quartzite along the Paloma thrust, but the movements appear to have been less intense than the Montosa shearing.

Granulation, flaser, mortar, and augen textures, solution, and recrystallization are conspicuous in both quartzite formations. Large grains develop at the expense of smaller ones. Solution at points of greatest pressure, and deposition where pressure is least have resulted in elongate grains with interlocking sutured contacts. Long axes of the quartz ellipsoids are oriented in general parallel to the sericite schistosity and the N. 20° E. trend of the range. Fracturing of the brittle quartzite is particularly prominent adjacent to the Montosa thrust. The force of the Paloma thrusting appears to have been less great or applied slowly over a long period of time. If intensive fracturing occurred in the White Ridge quartzite it has since been obscured by recrystallization. In the lower beds of this formation there are very few schistose zones along which slippage and relief of pressure might have occurred. The result is that the quartz has apparently borne the major readjustment by recrystallizing into long lenticular grains, which have ratios of length to width commonly as much as 10 to 1.

PALEOZOIC STRATA

PENNSYLVANIAN

General features.—Some time after the intrusion of the Los Pinos and Priest granites but presumably still in pre-Cambrian time, the rocks of the Los Pinos district were tilted steeply to the west. The resulting elevated areas were locally reduced to a surface of low relief which were observed does not exceed 100 feet. Over this eroded surface the Pennsylvanian seas advanced. The inundation appears to have progressed northward from southern New Mexico where Devonian and Mississippian rocks occur. Strata belonging to these periods are reported as far north as the Ladrones Mountains, about 30 miles west of the Los Pinos district. But their absence in the Los Pinos Mountains, and in the region to the north and east, suggests that when such deposition was in progress the latter section of New Mexico was emergent. Gradual encroachment of the seas into the northeastern section of New Mexico is inferred from the report of Lindgren, Graton, and Gordon (1910, p. 30), who state that an erosional interval between Mississippian and Pennsylvanian strata does not appear likely because of the absence of any structural discordance between the two systems of rocks. However, more recent information by Thompson (1942, p. 28) is that nowhere in New Mexico has the lowermost strata of Pennsylvanian age (Derry series) been observed to rest conformably upon older formations. Thus the direction of advance of the Pennsylvanian seas is a matter which is problematical and can be decided only when additional information is supplied.

In this Pennsylvanian sea more than 1000 feet of sandstones, shales, and limestones was deposited, constituting what has been called the Magdalena formation (Gordon, 1907, p. 805–816). The Magdalena actually embraces all strata within

the Pennsylvanian of New Mexico and is widespread except for the regions of the Zuni Mountains, Pedernal Hills, and some of the northeastern part of the State. Typical Magdalena strata consist of massive beds of buff sandstone and gray limestone, but along the east side of the Sangre de Cristo Mountains they are represented by gray to red sandstones (Darton, 1928, p. 179–180) and elsewhere they contain black silts, shales, dark silty limestones, gypsum, and red beds (Thompson, 1942, p. 17). Strata classified as Magdalena range in thickness from 500 feet, in the Nacimiento Mountains, to more than 3500 feet in the Sangre de Cristo Range.[3] Other reported thicknesses in mountain areas are 900 feet in the Sandias, 1100 feet in the Magdalenas, 1500 feet in the Sacramentos, and 2000 feet in the San Andres Mountains (Darton, 1928, p. 18–19).

Herrick (1900, p. 115) first subdivided the Magdalena formation into a basal group known as the Sandia; a sandstone, the Coyote; and at the top a siliceous limestone containing a large form of *Fusulina*. This *Fusulina*-bearing limestone was called the Madera by Keyes (1905, p. 22). Later Keyes (1906, p. 154) subdivided the Pennsylvanian into the Ladronesian at the base and the Manzanan at the top. The Manzanan was further subdivided from the base to the top (although the basis was not indicated) into the Sandia shale, Montosa limestone, Coyote sandstone, and Mosca limestone. Ellis (1922, p. 16–20) briefly described the Magdalena, calling attention to the sandstones of the Sandia formation and the massive limestones of the Madera formation, but he failed to establish any delimiting boundaries. In attempting to redefine those formations Needham (1937, p. 14) stated that "the plane of division between the two (Sandia and Madera) is so inconsistent and the lithologic character of the Pennsylvanian rocks varies to such an extent from place to place that divisions corresponding to the Sandia and Madera formations cannot be recognized in many parts of the state". He (1937, p. 14) demonstrated that the Magdalena can be subdivided into two distinct faunal zones, a lower section characterized by the fusulinids *Fusulina*, *Wedekindellina*, *Staffella*, and *Ozawainella;* and an upper zone characterized by the fusulinid *Triticites*.

Thompson (1942, p. 26–27) applied this faunal zoning in greater detail and showed that four large units of the Pennsylvanian could be established upon the basis of different genera of fusulinids. Thompson proposed abandoning the name Magdalena and substituting (oldest to youngest) the names Derry, Des Moines, Missouri, and Virgil. In Thompson's (1942) report each of the series is divided into group and formational units chiefly upon lithologic characteristics; but, as he (1942, p. 30, 41, 67, 83) states, the lithologic variation is great from locality to locality. Therefore boundaries established on the basis of lithologic characteristics do not seem to be of particular value outside the area of the type locality. This variation in lithologic characteristics is particularly true of the Pennsylvanian strata of the Los Pinos Mountains, and the only satisfactory means of subdivision is on the basis of faunal zones established by Needham (1937), Wilpolt (1942), and Thompson (1942).

The subdivisions established by Needham, Wilpolt, and Thompson are fundamentally identical. Needham and Wilpolt recognize a lowermost group of rocks in which they were unable to find *Fusulina*. This was called the *Fusulinella* zone of the

[3] Thompson (1942, p. 18) reports the thickest section of Pennsylvanian rocks in New Mexico occurs in the Sangre de Cristo Range where 3500 feet of strata has been assigned to the Des Moines series.

Magdalena formation by Needham (1940) and the Sandia formation by Wilpolt (1942). Thompson (1942) found the fusulinids *Millerella*, *Ozawainella*, *Eoschubertella*, *Profusulinella*, *Pseudostaffella*, and *Fusulinella* in these strata and named them the Derry series. Above this series Needham recognized a sequence of strata bearing *Fusulina*. This he referred to the zone of *Wedekindellina* and *Fusulina* of the Magdalena. Wilpolt (1942, p. 30) recognized the same zone in the Los Pinos Mountains but referred to it as the *Fusulina* zone of the Madera formation. The fauna of this zone corresponds to that in the Des Moines series of Thompson (1942, p. 40). Needham and Wilpolt recognized a lower and upper *Triticites* zone in strata which they called Magdalena and Madera, respectively, whereas Thompson assigned them to the Missouri and Virgil series.

Thompson's series subdivisions have been adopted for use herein since they conform to standard terminology for Pennsylvanian strata. Clearly they are also more indicative of stratigraphic position than terms such as Magdalena, Sandia, and Madera, which in previous usages have been referred to several different stratigraphic horizons and to strata in which specific positions are in doubt. Subdivisions below series designated by Thompson, have not been used by the present writers since the difference in rock facies between Thompson's type sections and their stratigraphic equivalents in the Los Pinos Mountains creates some uncertainty in their identification.

Cyclical sedimentation.—The difficulty of distinguishing subdivisions of the Pennsylvanian strata on the basis of their lithologic characteristics results from the tendency for the rock facies to change along the strike and the repetition of thin beds of similar appearance throughout hundreds of feet of sediments. It becomes impossible to select key horizons which may be positively recognized in the field over an extended area. The correlation of stratigraphic horizons becomes extremely difficult, and the results uncertain. In the Los Pinos Mountains two facies of cyclical sedimentation can be recognized; a type associated with the Derry series in which sandstones predominate, and a type associated with the Des Moines and Missouri series in which limestones and shales are most common. Nevertheless each series contains the same types of rocks; the distinction is chiefly in their relative thicknesses and in their order of repetition.

Rock types.—Since the entire Pennsylvanian in the Los Pinos Mountains consists of a repetition of certain distinctive rock types each of these is described in detail. Except for the basal conglomerate, they form units of a sedimentary cycle but they are not necessarily in the order in which they occur in the field.

1. Basal Conglomerate: Wherever the contact between the pre-Cambrian rocks and the Derry series is observed a basal conglomerate is present. Except for one locality to be described below, this conglomerate is uniform in appearance and thickness. Nowhere was it observed to exceed 15 feet in thickness and commonly it is less than 5 feet. It lies on the slightly irregular surface of pre-Cambrian rocks and in places, as at the base of Turret Mesa, appears to merge into 2 or 3 feet of coarsely granular gruss overlying the granite. Elsewhere, as at the base of the eastern slope of Tongue Ridge, the conglomerate lies with sharp contact upon the underlying schist.

The conglomerate is uniformly light gray to grayish buff and consists of angular to

subangular pebbles of milky quartz ¼–3 inches in diameter. The pebbles are generally uniform in size, approximately an inch in longest diameter, but are somewhat longer in the lower 3 feet of the bed; they constitute about 70 per cent of the rock. A noteworthy feature is the absence of fragments of schist, granite, and rhyolite which crop out in the region and upon which the conglomerate rests locally. The quartz fragments, however, appear to be identical with the quartz in the numerous quartz veins cutting the pre-Cambrian rocks. Most of the pebbles are somewhat elongate, and there is a tendency toward a rude parallelism with the bedding. Such an orientation has been somewhat exaggerated by shearing between the schist and conglomerate contacts on the east side of Tongue Ridge.

The matrix consists chiefly of particles of granule and very coarse sand size. Such grains are angular to subangular and are somewhat darker gray than the associated quartz pebbles. Occasional fragments of weathered feldspar are present, and the whole is firmly cemented with silica into a quartzose rock.

Exception to the normal facies of the conglomerate occurs in the exposure west of the Paloma fault (Pl. 1, locality D14). The outcrop is not extensive, and the conglomerate appears as a thin plaster upon the pre-Cambrian strata. The rock is buff or gray with a dark-gray or brown matrix and contains well-rounded fragments of all the pre-Cambrian rocks in the Los Pinos Mountains. Quartzite, Blue Springs schist, Sevilleta rhyolite, Los Pinos granite, pegmatite, and hornblendite as round boulders exceeding 8 inches in diameter are common, whereas fragments ⅛–¼ inch in size of the same materials are also present but are chiefly angular. Generally the matrix constitutes a small part of the whole of the conglomerate, but it is sufficiently abundant to cement the fragments. Pre-dominantly the matrix consists of angular quartz grains, but much is also orthoclase of rather pronounced red color and otherwise seemingly unweathered. Biotite is also prominent as rounded grains apparently unweathered. The conglomerate weathers to a deep brown to red brown somewhat like that of the Permian strata with which it might be confused. Nevertheless, despite its isolated occurrence it is presumed to be of Derry age because it contains no fragments of rocks younger than the pre-Cambrian.

2. Light-Gray Sandstone: Coarse-grained sandstones, locally conglomeratic and dominantly composed of fragments of granule size, occur commonly in the Derry series and less frequently in the younger series. Such beds are almost without exception massively bedded, cross-laminated, and readily distinguished from the olive-drab sandstones common in the Des Moines and Missouri series. Generally the very coarse or conglomeratic facies consists almost entirely of angular fragments of quartz ranging in size from fine sand to pebbles, occasional pebbles of pre-Cambrian rock, and flakes of muscovite sometimes a quarter of an inch in diameter. Despite the range in fragment size, the light-gray, buff, or nearly white color, coarseness of grain, and dominance of quartz particles characterize this type of strata so that it is recognized in the outcrop from some distance. Everywhere the rock is well cemented, but it is by no means quartzitic.

In Sierra Montosa near the base of the Pennsylvanian some of the sandstones are darker gray or even reddish gray due to the presence of iron oxide in the cement; in Tongue Ridge pyrolusite in these sandstones produces a mottled appearance.

Locally in Sierra Montosa such beds are arkosic and are characterized by a green color[4] despite their high feldspar content. The arkosic facies is always finer-grained, and its cement is partly calcareous in contrast to the nonarkosic facies which has a siliceous and ferruginous cement. Also this type of occurrence is more frequently observed in the Des Moines than in the Derry series.

Many beds of the coarse-grained sandstones type rade vertically, within 1 or 2 feet, into a granular limestone while maintaining such structural characteristics as cross-lamination. This change in lithology, although common and best illustrated in the sandstones, is observed also in strata of other types. The gradation is accomplished by the addition of increasing amounts of calcareous material much of which is crystalline calcite commonly in grains ranging up to a quarter of an inch in size. These are seemingly not detrital grains since their outline is angular, and they are associated with similar grains of much smaller size forming the cement. Other calcareous matter is clearly detrital in origin and consists of well-rounded fragments of brachiopod shells, crinoid stems, and corals. As the amounts of these materials increase and more of the organic remains are preserved, a granular limestone results which occasionally resembles coquina. This feature is well developed in the exposure of the Derry series in Turret Mesa.

3. Olive-Drab Sandstones: Olive-drab sandstones are structurally and lithologically distinct from the light-gray sandstones. The former are more common in the Derry and Missouri series than in Des Moines or Virgil strata, but light-gray sandstones predominate in the Derry series. Ordinarily the two types are not gradational, but occasionally, as in the strata exposed in the lower part of the east side of Tongue Ridge, the olive-drab sandstones grade into the coarse-grained light-gray type. The olive-drab sandstones are generally thin-bedded, fine-grained, and very micaceous; in places they are silty and cross-bedded. Their thickness is generally less than 5 feet; 2 to 3 feet is common. Strata of this type are largely quartz, feldspar, muscovite, and biotite grains bound by a calcareous cement. Frequently the calcareous portion increases to the extent that the rock becomes a fine-grained, arenaceous limestone. The only fossils are plant forms. These are fragments too small for positive identification of genera but doubtless are representative of those previously reported from the Magdalena (Darton, 1928, p. 112). Not uncommonly modifications occur of the standard color to gray, yellow buff, or brown, particularly on the weathered surface, and in such instances the gray is associated with an increase in the calcareous content and a decrease in grain size.

4. Olive-Drab or Gray Micaceous Shale: Shales containing much muscovite are usually associated with the olive-drab sandstones. Such shales grade vertically into the sandstones and into gray nonmicaceous shales. Where such gradations occur, the nonmica-bearing shales generally contain marine fossils although the micaceous and sandy portions contain fragments of plants. This is well illustrated in a 25-foot bed cropping out along Highway 60 just west of where steeply inclined ridges of massive limestone of the Des Moines and Missouri series are exposed. Here the lower portion of the shale is micaceous and sandy and contains plant fragments,

[4] The degree of green color is controlled by the amount of chlorite present.

whereas the remainder of the stratum is a thinly bedded clay shale containing a profusion of the brachiopod *Derbya crassus*. Generally where plant forms are common marine fossils are absent, but where marine forms are abundant an occasional plant fragment occurs.

In a few instances chiefly along the exposures of the Missouri series in Abo Canyon, the micaceous shale is dark gray and finely laminated to the extent of breaking into laminas of paper thinness. In such cases gypsum is associated with the strata and is found as small veinlets and nodules. Lenticular-shaped plant-bearing ironstone concretions may occur also. Where fossils are present outside the concretions they are plant fragments and ostracods.

5. LIMESTONES: Limestones are common in all of the series except the Derry and may be classified into three textural types as follows:

(a) Massive gray limestone. Strata corresponding to this type are generally light gray, dark gray, or buff and are light buff gray when weathered, but a few exposures are gray brown or deep red brown. Characteristically two types of surfaces are developed by weathering. One is smooth and plane, whereas the other is pitted by solution into a *Rillensteine* surface. The rock is finely crystalline, almost lithographic in texture, and breaks with conchoidal fracture. Commonly the bedding is regular in units 2 to 3 feet in thickness, but more often the bedding planes form wavy lines, and the rock is slabby in layers 2 to 3 inches thick. In many localities, particularly along the Paloma and Montosa faults, the rock has been shattered, and the openings sealed with iron-bearing calcite. The fracturing is best seen on weathered surfaces where the iron-bearing calcite is indicated by the limonite stain. Chert is also common in nodules or veinlets but most often as thin quarter-inch to half-inch layers along bedding planes and joint surfaces. In such occurrences the chert has irregular shapes which are prominent in etched relief on weathered surfaces. Small amounts of green chert were observed in strata of Virgil age, jasper in the lower Permian, and gray, iron-bearing flint locally in strata of all ages. Fossils, particularly brachiopods and fusulinids, are common in some layers. On weathered surfaces of the smooth type, fusulinids are so abundant as to develop a spotted appearance on the rock.

Limestones of this type commonly are intercalated with thin gray shale beds into which they grade. They are also gradational into another type of limestone herein designated as nodular limestone.

(b) Nodular limestone. Nodular limestones are closely related to the massive gray limestones since they commonly form the lower part of some of the thicker beds, but they also occur singly in layers which do not exceed 5 feet in thickness. These are gradational rocks since they commonly are associated with gray shales which contain calcareous nodules, and as these nodules increase in abundance the nodular limestone facies is developed. In other occurrences the nodular rock also increases in massiveness, and the nodules correspondingly decrease in number until the limestone is representative of the massive gray type. The nodules are light gray to dark gray, lithographic, and argillaceous or silty. The nodular limestone bed as a whole is usually fossiliferous, and in some localities the fossil content, particularly of fragments of brachiopod shells and crinoid stems, constitutes much of the matrix. Commonly

the surfaces of the nodules contain fossils, and the internal portions are barren. Still elsewhere the bed may be barren of fossils and consist of irregular nodules of limestone separated by thin films of shale. Ordinarily the nodules are 2 to 3 inches in their longest dimension and about 1 inch thick, but they may also be the size of a pea. Often the nodular character of the rock is not observed on the fresh surface, but weathering reveals its presence; the nodules are more resistant to solution than the surrounding matrix. The accentuation resulting from weathering is particularly well demonstrated where the nodules are large and are included in a somewhat argillaceous matrix. The softer shale is carried away, and an irregular and knobby surface of weathering results (Pl. 3, fig. 2).

(c) Granular limestone. Coarsely crystaline brown limestones which may weather gray are common in the Derry series but rare in the younger strata. These rocks are characterized by a profusion of fragments of shells of marine organisms which in some instances constitute the entire rock. The fossils are largely replaced by coarsely crystalline calcite, and on weathered surfaces the etching of such material results in a rough or vermiform surface. Cross-lamination is common, and the coarsely crystalline texture accentuates the development of the foreset beds. These limestones do not form prominent layers but are always less than 5 feet thick. Except for a few local instances, where they are slabby, the beds are massive. Characteristically they are gradational into the underlying or overlying rocks and merge into light-gray coarse-grained sandstones or massive gray limestones but never into the nodular limestones. Since they are transitional, they may be very arenaceous and grade from a sandy limestone into a calcareous sandstone. More often the amount of noncalcareous material is small.

Cycles within the series.—The semblance of orderly repetition of the rock types described above permits the recognition of certain cyclical units within each Pennsylvanian series. With the exception of some shale and sandstone beds, all these units consist of strata bearing marine organisms. The exceptional sandstones and shales, however, contain fragments of land plants which alone do not prove continental deposition. The cyclical deposition of the Pennsylvanian strata of the Los Pinos Mountains is therefore not representative of extensive fluctuations of the seas such as occurred in the Eastern Interior Coal Basin but is typical of marine deposition prevailing throughout New Mexico and Texas (Plummer, 1931, p. 259–269).

The cyclical units as established in the Los Pinos Mountains do not conform to the ideal sedimentary cycles proposed by Wanless and Shepard as representative of certain environments of deposition. Nevertheless, the sequence and lithologic character of the sedimentary cycles in the Los Pinos Mountains most nearly conform to the description of the standard neritic cycle (Wanless and Shepard, 1956, p. 1186)[5]. The differences appear largely in the Derry series where alternation between sand-

[5] The neritic cycle as postulated by Wanless and Shepard consists of the following arranged in ascending order:
(7) Shale, gray clay, may contain one or more beds of limestone.
(6) Limestone, light gray, pure, thick.
(5) Shale, black, fissile resembles that above coal in delta facies.
(4) Limestone, dense, usually in one bed.
(3) Shale and clay, poorly bedded, upper part resembles underclay.
(2) Limestone, marine fossils.
(1) Shale, sandy or clay, generally without marine fossils and with no marked break or a slight discontinuity at the base.

TABLE 3.—*Comparison of thickness of rock types in per cent of total thickness of measured sections in the Pennsylvanian system*

Type		Derry series			Des Moines series				Missouri series			Virgil series		
		Turret Mesa	Tongue Ridge	South Stadium Vy.	South Stadium Vy. (Incomplete Section)	Abo Ry Cut	Turret Mesa (Incomplete Sect.)	Tongue Ridge (Incomplete Sect.)	Dripping Springs	Near Abo Cut	South End of Mountains	Near Abo Cut	Highway 60	Dripping Springs
Sandstone, light gray, coarse	(2)	67	59	64	0	1		4	9	1	14			
Sandstone, olive drab, micaceous, fine-grained	(3)	12	16	19	0	0		3	22	14	19			
Shale, gray to olive drab, micaceous, silty	(4)	4	12	0	0	0		0	0	0	0			
Shale, black, fissile		5	4	0	0	0		0	0	0	0			
Shale, dark gray, argillaceous		0	0	0	0	4		0	32	1	0			
Shale, light gray, argillaceous		0	0	0	0	<1		0	7	23	20			4
Shale, green		0	0	0	0			0	0	3	0			
Limestone, gray to brown gray, dense, massive, maybe cherty	(5a)	6	6	10	37	94	100	21	26	57	30	100	100	82
Limestone, gray, nodular	(5b)	0	0	0	63	0		67	4	1	3			14
Limestone, gray brown, coarsely crystalline, arenaceous	(5c)	6	2	7				5	0	0	15			

stone and limestone is more frequent than in the sequence of shales and limestones described by Wanless and Shepard. These differences and the absence of disconformable contacts preclude the selection of the beginning of a cycle on any other than some arbitrary basis.

The persistence of thin formational units over widespread areas so characteristic of the Pennsylvanian strata elsewhere (Weller, 1931, p. 169; Wanless, 1931, p. 181; Moore, 1931, p. 248), is not to be observed in the Los Pinos Mountains. Individual strata are lenslike, and in sections through the same vertical thickness of rocks, but spaced a quarter of a mile apart, the same bed can seldom be recognized throughout. Nevertheless there is a distinct uniformity in the proportion of rock types within a given series, as shown in Table 3.

TABLE 4.—*Ideal cycle of sedimentation within the Derry series*

e. Limestone (type 5a), gray, fine-grained to lithographic texture, thinly bedded, usually present only near top of the Derry series.
d. Limestone (type 5c), brown to gray brown, coarsely crystalline or granular, extremely fossiliferous, commonly grades upward into sandstone (a) when (e) is absent.
c. Shale (type 4), gray to olive drab, micaceous, sandy (not common).
b. Sandstone (type 3), gray to olive drab, micaceous, calcareous, locally grades upward into shale (c).
a. Sandstone (type 2), gray to light gray, micaceous, very coarse-grained, locally conglomeratic and arkosic, cross-bedded, commonly grades upward into sandstone (b).

Despite the errors introduced by several incomplete sections in the Des Moines, each series is characterized by a dominance of certain rock types. The Derry series contains a preponderance of light-gray coarsely granular sandstone, and olive-drab, finely granular, micaceous sandstone. Strata of Des Moines age are characterized by beds of nodular and dense massive limestones; the Missouri series contains chiefly gray argillaceous shales, olive-drab micaceous sandstones, and massive limestones. The Virgil series is almost exclusively dense, massive limestone. Such differences characterize the series, but, except for the Virgil series, there appears to be within each some orderly repetition of beds to constitute a cycle of sedimentation. In each the cyclothem differs, and hence this may be used also to aid in the recognition of the series. Comparison of the actual stratigraphic sections and the order of stratigraphic occurrence within the cyclothem reveals that there are many departures from the regular order of the cycle which characterizes that series. Such departures appear to be chiefly due to the high degree of lateral gradation and interdigitation in these sediments. Nevertheless repetition of certain sedimentary types prevails. In the Derry series the sequence of occurrence is as listed in Table 4. Since the units of the cycle are not separated by an unconformity the selection of the basal bed of a cycle is arbitrary. The coarse-grained sandstone has been selected as marking the beginning of a new cycle because it indicates an abrupt change in sedimentary conditions. This is demonstrated by the rapid accumulation of coarse debris as indicated by the "torrential" type of cross bedding frequently found in these sandstones.

Generally the sandstone is conglomeratic (pebbles $\frac{1}{4}$–$\frac{1}{2}$ inch in size) or extremely coarse-grained near the base and becomes finer-grained toward the top. The finer-grained section is usually more micaceous and thinly bedded. In a few places there

is a gradation into the olive-drab sandstone where scattered occurrences contain fragments of plants. Although these must indicate the presence of land near by there is no specific evidence that they were not deposited in a marine evnironment. This is supported by the gradation into definitely marine strata and the absence of any disconformable contacts between the plant-bearing sandstones and the strata beneath. Elsewhere the finer-grained section of the sandstone becomes increasingly calcareous in its upper portion and merges into a gray shale or a gray-brown limestone.

TABLE 5.—*Ideal cycle of sedimentation in the Des Moines series*

c. Shale (type 4), gray to olive drab, micaceous, silty or sandy, may grade into shaly sand-stone.
b. Limestone (type 5a), gray, fine-grained to lithographic texture, silty, massive or thin-bedded.
a. Limestone (type 5b), light gray to dark gray, nodular, bedding may be massive or slabby and irregular.

Similar gradations occur between the calcareous sandstone and granular limestone. In turn the coarse-grained limestones are generally overlain by a fine-grained, almost lithographic, gray limestone, usually massive but which may also be irregularly and thinly bedded. Such limestones mark the completion of a cyclical unit, and they are overlain by the conglomeratic or coarse facies of light-gray sandstone of the cycle above. Vertical gradation between all the units of the cycle is the rule rather than the exception and indicates the slowness of change in conditions of deposition.

The Des Moines series is not characterized by a diversity in lithologic type but marks a change in character of sedimentation from that in the Derry series. Table 5 shows a cyclical unit of the Des Moines which in effect is chiefly limestone. The gradation into such conditions of sedimentation begins near the close of Derry sedimentation since in the upper part of that series fine-grained, gray limestones make their appearance. These become very prominent in the interval of Des Moines sedimentation.

Strata of the Missouri group are characterized by: (1) the predominance of shale and limestone, and (2) the presence of fragments of plants in certain shale and sandstone beds. Rocks belonging to this series show repetitions of beds as listed in Table 6. In general the lower part of the Missouri contains more shale and sandstone than the upper part, which is similar to the overlying Virgil series. No distinct lithologic break is recognized between the Missouri and the Virgil, and the conditions of predominant limestone deposition characteristic of the Virgil were initiated during the close of Missouri deposition.

The presence of plant fragments in sandstones and shales in the lower parts of the Missouri sedimentary cycle is not considered to indicate intervals of continental deposition but rather shallow-water marine or estuarine environment. Land plants carried by streams to such environments were incorporated and preserved within the inorganic debris. This interpretation has been based upon the lack of proof of the continental origin of the plant-bearing strata. The deposits do not lie in channels, nor are there indications of intervals of erosion between the deposition of the strata. Likewise mud cracks and rain-drop imprints are absent. On the contrary, there is commonly a rapid vertical gradation between strata containing plant fragments and

marine organisms. Such strata also interdigitate laterally in distances of several hundred feet; the plant fragments are scattered throughout the beds and are not concentrated in carbonaceous streaks.

The presence of the plants, however, does indicate the existence of near-by emergent areas, and Darton (1928, p. 257) reports a coal bed in the Magdalena near Lamy, New Mexico, although there is no indication that this bed is of Missouri age.

TABLE 6.—*Ideal cycle of sedimentation in the Missouri series*

e. Limestone (type 5a), gray to brown gray, dense but also crystalline and fossiliferous.
d. Limestone (type 5b), gray, nodular, fossiliferous.
c. Shale (type 4), dark gray, micaceous, silty, weathers to a cinderlike surface, contains marine fauna usually brachiopods (not common).
b. Shale (type 4), gray to olive drab and green gray, micaceous, silty or sandy, may weather to cinderlike surface. Contains plant fragments.
a. Sandstone (type 3), gray to olive drab, micaceous, cross-bedded, contains fragments of plants may grade upward into micaceous shale.

Strata of Virgil age in the Los Pinos Mountains show little tendency toward rhythmic repetition of beds. They are almost exclusively gray to dark-gray limestones, dense or finely crystalline, and somewhat cherty. The beds are chiefly massive and somewhat irregularly beded, but near Dripping Springs there occur some nodular limestone and gray marine calcareous shale in the sequence of beds.

PERMIAN

General features.—Strata which lie upon the Virgil series in the Los Pinos Mountains are red and, except for a limestone near the base of such sediments, differ markedly in lithology from the strata of the Virgil and older series of the Pennsylvanian. The red rocks constitute part of a Permian formation, which was named the Abo by Lee and Girty (1909, p. 12) after its occurrence in Abo Canyon. They described the Abo as follows:

> "It is the basal member of the Manzano group and rests unconformably upon the Magdalena group. It consists of coarse-grained sandstones, dark red to purple in color, and usually conglomeratic at the base, with a subordinate amount of shale which attains prominence in some places."

Recently some question has arisen concerning the lower boundary of the Abo in certain sections of New Mexico because of the presence of red sediments reported in the upper part of the Pennsylvanian, and an unconformity at the top of a Permian limestone formerly incorporated within the Abo. The red strata have been mentioned by Lee and Girty (1909, p. 33), Ray and Smith (1941, p. 183–186), and Thompson (1942, p. 67) in localities some distance from the Los Pinos Mountains. In the Los Pinos Mountains no such gradual change from red Pennsylvanian to red Permian sediments can be observed; rather there is an abrupt change from the gray and buff limestones of the Virgil to Permian red sandstones and shales. For reasons to be mentioned later the appearance of reddish rocks in the locality concerned in this report is selected by the authors as the base of the Permian.

That part of the Permian extending upward from the boundary thus defined to the top of the red sediments is herein subdivided into two formations: a lower one

beneath an unconformity at the top of a marine limestone, and an upper unit extending from this unconformity to the base of the overlying formation, the Yeso. The upper unit is that which Needham and Bates (1943, p. 1653–1656) redefined as the Abo formation, and for the lower unit the name Aqua Torres formation is proposed. This distinguishes strata of Wolfcamp age, which have been recently classified as the upper part of the Magdalena, from the section of the Magdalena of Virgil age.[1]

Aqua Torres formation.—Strata of the Aqua Torres formation consist of a thin conglomerate at the base above which lies a sequence of arkoses, red sandstones, red shales, and nodular limestones, and at the top a gray, massive limestone. Such strata are exposed in the Arroyo Aqua Torres in the southeast portion of the mountains and also along Highway 60 east of the thrust faults.

In nearly all the localities, a conglomerate forms the base of the red sediments. This conglomerate is everywhere less than 5 feet thick, is characteristically brown and contains pebbles 1 to 2 inches in longest dimension, of quartz, gray limestone, and an occasional red limestone, in a fine-grained calcareous and well-cemented matrix.

Locally where it crops out near Highway 60 the conglomerate is overlain by a white marl largely unconsolidated and barren of fossils. Over most of the area the latter stratum is missing, and a very coarsely granular, red-brown arkose lies upon the conglomerate. This coarse arkose consists of well-cemented grains of quartz and orthoclase in the proportion of about 20 per cent orthoclase to 80 per cent quartz. It contains some fragments of quartz which may exceed half an inch in length, is prominently cross-bedded, and weathers into great rounded masses and boulders. In its upper part this bed which reaches a thickness of 40–50 feet becomes gray pink, is much finer-grained, and fragments of plants are common. The arkose is best exposed in an area 1 to 2 miles south of Highway 60 east of the thrust faults, but southward these beds change their facies and become red-brown medium-grained sandstones. Here the particles consist almost entirely of subround to subangular quartz grains cemented with hematite.

Above the coarse arkose of the central part of the area are several layers, each approximately 1–2 feet in thickness, of gray to purplish-gray nodular limestones separated by equally thin layers of shale. The nodular limestones consist of rudely rounded or ellipsoidal calcareous nodules cemented in a calcareous but slightly more argillaceous matrix. The matrix is predominantly gray but has in places purplish streaks which tend to give the entire bed a purplish cast, particularly on the weathered surface. Locally the matrix contains much shale, and the nodular limestone layers are thin, but elsewhere, such as along the northern edges of the fault blocks at the south end of the range, the shaly part diminishes, and the nodular limestone thickens to 5 feet.

The nodules are for the most part approximately 2–3 inches in diameter, but they are not uncommonly as large as 5 inches. Their surfaces are irregular and pitted. The internal structure is dense or finely crystalline and shows no suggestion of concretionary or algal structures. Nodular limestone layers in approximately

[1] For a thorough discussion of this problem *see* P. B. King (1942, p. 674 *et seq.*) and R. E. King (1945).

the same stratigraphic position have been observed in exposures along the highway east of Mt. Paloma, also at the south end of the range, and it is presumed, therefore, that this is a continuous stratigraphic marker near the base of the red sediments. The nodular limestones are sparingly fossiliferous, but two fusulinids—*Schwagerina* and *Triticites*—have been identified from this horizon at several localities in the southern part of the range. Alternating red and gray nonfossiliferous sandstones, ranging from 15 to 40 feet thick, lie upon the nodular limestones.

A limestone lithologically and generally like those in the Virgil group lies upon the sequence of red sediments. This limestone is best exposed immediately south of the highway and east of the thrust faults, where it is 25–30 feet thick; east of Mt. Paloma, owing to pre-Abo erosion, it is less than 3 feet thick. Locally it is missing 2 to 3 miles south of Mt. Paloma but reappears again near the south end of the range. The rock is light gray to medium gray and weathers to a dark gray or brown gray. It is dense or finely crystalline and is bedded in massive layers of a foot or more in thickness. In these aspects it looks much like the limestones of the Virgil, but there is a difference in one respect—namely, the shells of the megascopic fossils which it contains have been partly or wholly replaced by jasper. Exceptions to this replacement are rare, particularly in the exposures at the south end of the range. No other bed in the district shows similar selective replacement, and hence, if this feature is widespread in districts outside the Los Pinos Mountains, it would provide a suitable stratigraphic marker. In the exposures near Highway 60 the limestone is not cherty, but near the basalt much flint occurs as irregular nodules several inches in longest dimension associated with bands and irregular masses of jasper. The increase in the amount of jasper in the vicinity of the basalt flow strongly suggests that the source of the jasper has been hydrothermal activity connected with the late Tertiary or Quaternary volcanism.

Abo formation.—Disconformably upon the Aqua Torres formation are alternating beds of coarse sandstone, siltstones, and shales, of a characteristic hematite red color and exceeding 500 feet in thickness where they are best exposed east of the Montosa and Paloma thrusts. Most of the beds are only 2 to 3 inches in thickness, and outcrops are generally covered with much slabby debris. Such beds are typical of the Abo formation as now defined; a detailed description has been prepared by Needham and Bates (1943, p. 1654–1656).

Yeso formation.—Beds younger than the Abo formation do not crop out within the confines of the Los Pinos Mountains, but at the extreme southwestern edge of the mountain area strata of the Yeso formation are exposed. Such beds are also commonly exposed where the pediment surfaces west of the mountains have been dissected. The Yeso formation is recognized by the appearance of gray to buff limestone beds, several feet thick, separated by red-brown beds of sandstone and siltstone. The limestones are dense or subcrystalline, well jointed, but break into splintery fragments when struck. Stylolites are common. Above the lower 100 feet, the sandstones become more yellow, the limestones become more irregularly bedded or appear brecciated, and thick beds of gypsum occur.[7]

[7] For a detailed description of the Yeso formation the reader is referred to Needham and Bates (1943).

PERMIAN-PENNSYLVANIAN BOUNDARY

The authors have placed the boundary between the Pennsylvanian and Permian strata in this locality at the first appearance of red sediments. The placing of such a boundary is apparently unsatisfactory in other sections of New Mexico, where strata of Virgil age are red, but in the Los Pinos area the lithologic and faunal boundaries nearly coincide. Strata of Virgil age in the Los Pinos Mountains are characterized by *Triticites ventricosus*, which Needham states (1940, p. 178) marks the highest Pennsylvanian strata in New Mexico. Approximately 40 feet above the base of the red sediments in the Los Pinos area occur the lowermost strata in which was found a diagnostic Permian (Wolfcamp) fusulinid, *Schwagerina emaciata*. Such strata are the previously described gray to purplish-gray, nodular, thin limestones in the lower part of the Aqua Torres formation. There is no faunal evidence, however, to indicate that the beds below the *Schwagerina*-bearing limestones are Permian. Nevertheless certain indirect evidence suggests the Permain age of these lower red strata: (1) The conglomerate at the base of the red beds contains fragments of Pennsylvanian limestone. This indicates a post-Virgil interval of erosion. (2) With the possible exception of the basal red-bed conglomerate, which contains fragments of brachiopod shells, the strata are continental in type and hence indicate a withdrawal of the seas following the deposition of the last definitely identifiable Virgil strata. (3) The red color of the beds and the alternation of marine and nonmarine sedimentation characterize the beds above the *Schwagerina*-bearing strata just as they do below. (4) Outside the Los Pinos Mountains the contact between the Magdalena and the overlying red sediments (Abo, as originally defined) is reported as sinuous and unconformable (Darton, 1928, p. 20; Blanchard and Davis, 1929, p. 957).

The problem is further confused by the lack of uniformity in the delineation of the base of the Abo which until redefined by Needham and Bates generally was considered to mark the boundary between the Pennsylvanian and Permian strata.

As now defined (Needham and Bates, 1943, p. 1654) the Abo is restricted to the nonmarine portion of reddish-brown sandstones and shales lying above a Permian limestone containing a marine fauna. Since this is the upper massive limestone of the Aqua Torres formation in the Los Pinos area, more than 100 feet of strata, which the authors consider Permian, lie beneath the Abo. This thickness of strata is not uniform since the base of the Abo as stated by Needham and Bates lies upon an unconformable surface. In the Los Pinos area this is clearly apparent in the thinning of the limestone member of the Aqua Torres formation southward from Highway 60, its local absence south of Mt. Paloma, and the presence of beds of the Abo at that stratigraphic horizon. The magnitude of the unconformity merits further regional study since it has considerable bearing on the stratigraphic equivalents of the Abo and the Aqua Torres formations elsewhere.

STRUCTURE

GENERAL STATEMENT

The major elements of structure in the Los Pinos Mountains are: (1) westward dipping pre-Cambrian sediments, rhyolite flows, and intercalated basic sills, dikes, and flows; (2) the coarse-grained Los Pinos granite intrusion with its associated

pegmatites, quartz veins, and wide border zones of granitized schist; (3) the nonconformable contact between the pre-Cambrian basement and the overlying Pennsylvanian sediments; (4) thrust faults which place pre-Cambrain rocks against and over Pennsylvanian and Permian sediments; (5) normal faulting and tilting of Pennsylvanian and Permian formations.

PRE-CAMBRIAN BASEMENT

Nearly 12,000 feet of quartzites, siltstones, schists, and rhyolites, with intercalated basic schists, makes up the pre-Cambrian formations which are intruded by the Los Pinos granite. This thick series shares a remarkable persistency in strike and dip directions, averaging N. 20° E. and dip of 45° W. Local exceptions to the regional structures are not uncommon, but where outcrops are traceable for any considerable distance the average directions prevail. Steepening of dip characterizes the quartzite beds adjacent to the main thrust faults, and a similar steepening occurs above local shear zones where massive quartzite beds moved as a unit over thick sericitic schist zones acting as a plastic lubricant.

Drag folds occur in several of the schistose beds and rarely are more than a few inches in greatest dimension. In the thicker zones of schist, there is much distortion, indicating more than a single period of deformation. One exception to the small drag folds occurs along the Montosa thrust fault, approximately half a mile southwest of Highway 60, where a fold of approximately 5 feet in diameter developed by dragging of the Sais quartzite over basal conglomerate beds of Pennsylvanian limestone. In no outcrop, however, do the structures leave any doubt about the upward movement of overlying beds, which moved up-dip from the west.

Schistose beds due to dynamic metamorphism characterize the pre-Cambrian section. Sericite schist forms 60 per cent of the Blue Springs formation, originally siltstone and shale. Both quartzite formations and the rhyolite flows show numerous shear zones that have been more or less completely recrystallized to sericite schist. All gradations exist between the highly sericitic schists and the schistose beds of quartzite, siltstone, and rhyolite. In all outcrops the basic rocks are altered to schists. The schistosity approaches parallelism with the strike and dip of the bedded formations. Locally the thicker zones of schistose structure are much contorted, and extremes of shearing, folding, and plastic deformation are exhibited. But even in such areas there are many relicts of earlier structures that accord with regional westward dips and movements up-dip from the west.

Fracture cleavage is the prominent type of rock failure in the massive beds of the Sais and White Ridge quartzites. Flow cleavage is developed in the impure quartzites and interbedded shales and siltstones. Excellent examples of the relationships existing between bedding, joints, shear fractures, and flow cleavages are abundant in all sections across the pre-Cambrian rocks. The attitudes of fracture and flow cleavages vary with respect to one another according to the degree of shearing and the brittleness or plasticity with which the separate beds reacted to deformation. In all outcrops the upward movement of overlying beds is apparent.

Cross-bedded structures in the coarser-grained quartzites are usually discernible, and their truncation indicates that attitude of the strata is normal. Gradations of

grain size are less easily recognizable, but where found they corroborate the evidence of the truncated cross-bedding that the beds are not overturned.

The rhyolite flows show all degrees of alteration from porphyritic aphanites in which the groundmass shows no evidence of shearing to schists that are almost completely converted to sericite. In the more schistose flows, small drag folds, fracture cleavage, and foliation all indicate accordance with similar structures in the overlying sediments.

The great thickness of the pre-Cambrian section raises the question of whether isoclinal folding may be present. In areas studied by the senior author in Colorado (Stark, 1935, p. 4; Stark and Maxson, 1939, p. 1532) isoclinal folding characterizes the pre-Cambrian sections, and similar structures were expected in the Los Pinos region. Careful search was made for any structures that might indicate overturning, but, except for the small drag folds confined to schistose beds and local crumpling in the thrust fault zones, no evidence was found of close folding or repetition of beds. On the other hand, almost all outcrops of any extent offer clear evidence that the sediments and flows form a continuous, westward-dipping series. Since the schists and flows continue west beyond the present flanks of the range but are covered by Cenozoic sediments, the pre-Cambrian is unquestionably much thicker than the section now exposed.

A great pre-Cambrian geosyncline in northern New Mexico is reported by Just (1937, p. 11) in which the formations range in thickness from 3½ to 7 miles. These consist largely of quartzites, schists, and lava flows intruded by granite. A brief trip through this region under the guidance of Mr. Just revealed many similarities to the Los Pinos section, and it seems not unlikely that future studies may establish a connection between these two pre-Cambrian areas.

LOS PINOS GRANITE

The central stocklike mass of coarse granite in the Los Pinos Range is probably continuous at depth with a much larger massive which crops out in the Manzano Mountains to the north. All facies of the Los Pinos granite, varying from faintly schistose structure near the core of the range to extremely schistose border zones, can be matched in outcrops of the Priest granite at the southern end of the Manzano Mountains.

In no outcrops is the Los Pinos granite wholly free from the schistose structure. Even in the most massive facies, in the center of the range, the biotite is foliated. All gradations exist between the faintly schistose granite and the pronouncedly foliated schist of the host rocks. The abundance of porphyroblasts of feldspar and quartz in xenoliths and bordering zones of schist indicates that granitization of the sedimentary formations was an important part of the intrusion process. There is no clear evidence of intrusive contacts, apophyses, or stringers suggestive of a viscous magmatic intrusion of the granite. The wide transition zones from granite into schist have been indicated on the areal map by stippling around the border of the granite, but this scarcely presents a true picture since the intermediate zones are so extremely gradual that sharp boundaries cannot be drawn.

At the south end of the outcrop the granite fingers out into schists forming a series

of projections parallel to the schistosity, but this resembles *lit-par-lit* injections less than a selective replacement by granitization along certain favorable zones in the sedimentary schists. Lens-shaped xenoliths of schist, ranging from a few inches to several tens of feet in length, exhibit all stages of granitization from areas containing only a few scattered porphyroblasts to others which are predominantly granitic and have only very faint outlines of the original inclusion. These schistose lenses show alignment and schistosity parallel to the general regional structures, N. 20° E., and they appear to be the last remnants of sedimentary schist replaced *in situ* by granitic juices rather than inclusions that have been oriented by flowage in a fluid magma.

True fluid intrusion is unquestionably represented in the pegmatite and aplite dikes. These range in width from thin stringers up to 50 feet, represent a late stage of the magmatic invasion, and, although cutting all parts of the granite, are especially numerous in the border zones. The quartzose vein-dikes, which in some outcrops may be traced into the feldspathic pegmatites, are more abundant in the quartzites, schists, and rhyolite flows. The dikes and veins show considerable conformity with the strike of the sediments, but a comparison of many measurements indicates that the majority cut across the dips of the beds at slight angles, show pinch and swell, and not uncommonly occur as vertical dikes.

FAULTING

General statement.—Sometime before the Quaternary volcanism the regionally west dipping pre-Cambrian structures were accentuated by thrust faulting from the west. Two large faults strike longitudinally along the range and dip in general parallel to the dip of the sediments and rhyolite. The overthrusting suggests correlation with similar movements in the Rocky Mountains which if correct would place the age as probably contemporaneous with the Laramide orogeny farther north.

Aerial photographs of the Los Pinos Mountains show prominent ridges representing tilted hogbacks that formed along the strike of two thrust faults on the east flank of the range. Of these the westernmost one has been named the Paloma thrust, and the easternmost one is called the Montosa thrust; the names were taken from two prominent mountains involved in the faulting.

The fault zones vary considerably in width and comprise many small thrusts instead of being single major breaks. The silicified breccia, which in most places marks the faults, attains a thickness of 50 feet in the Montosa thrust. Where vertical sections are exposed, as in the railroad cuts at Abo Pass, the faulted zones extend for several hundred feet and show extreme distortion in crumpling and fracturing of the beds.

One of the most interesting exposures of the Montosa fault is in the Santa Fe railroad quarries just south of Abo Pass. Here shattered Sais quartzite has been excavated almost to the limestone contact, and the quarry walls offer excellent vertical sections showing the multiple shear planes that make up the Montosa thrusting. Slickensided surfaces on successive quartzite beds are exposed for more than 400 feet along the south side of the quarry.

Paloma thrust fault.—The Paloma thrust zone extends from the southern end of

the Manzano Mountains, just north of Abo Pass, southward along the entire length of the Los Pinos area. The zone has an average trend of N. 18° E. and dips westward at angles of 40°–50°.

The White Ridge quartzite crops out on the upthrown side of the fault, from Abo Pass southward for two-thirds of its exposed length. On the downthrown side the Blue Springs schist acted as incompetent and plastic beds over which the massive quartzite was thrust from the west. A silicified fault breccia in the quartzite (Pl. 5, fig. 1), ranging in width from 15 to 30 feet, forms a prominent ridge in more or less continuous outcrop along the northern half and in scattered outcrops along the southern half of the fault zone. The thorough brecciation and subsequent silicification of this zone obscures the bedding in the quartzite, but in the few outcrops where it can be recognized a steepening of dip marks the fault zone.

In the southern third of the area the pre-Cambrian formations are covered by Pennsylvanian sediments, and the thrusting here has brought limestone against limestone. Greater distortion of beds in the fault zone at the northern end and apparently lesser displacement in the limestone beds at the south suggest that the throw of the fault continues to decrease from north to south.

The fault traverses the west flank of Sierra Montosa and has resulted in the scarp face of this section of the mountain. Here the throw has decreased to approximately 550 feet as indicated from an extension of the Derry series northward from Tongue Ridge and comparing its projected elevation with equivalent beds in Sierra Montosa. Southward the fault continues to decrease in throw until at the limits of the mapped area it approaches the magnitude of 100 feet. (*See* sections A-A′ to J-J′ of Plate 7.)

Montosa thrust fault.—An eastern zone of faulting, the Montosa thrust, in general parallels the Paloma thrust fault and is responsible for the steeply dipping hogback ridges that form prominent features of the eastern front of the Los Pinos Range. Beginning north of Abo Pass, where the two faults are less than a quarter of a mile apart, the zone between them narrows to 500 feet for a mile south of the pass, then widens gradually to a maximum width of 1¼ miles in the vicinity of Sierra Montosa. From here the distance between the two faults narrows again to the south and for the last 5 miles is only a few hundred feet.

The Montosa thrust slice brings Sais quartzite against Pennsylvanian limestone along the northern 5 miles of the fault; Blue Springs schist against Pennsylvanian limestone along the central 3½ miles; and from here southward the fault is entirely in the Pennsylvanian and Permian sediments. Just north and south of Abo Pass, the strike is N. 25° E.; a mile south of the pass it trends N. 3°–5° E. and continues in a slightly sinuous line to where it parallels the highway with a N. 10° W. trend. Southward from this point for 2½ miles the strike averages N. 25° E. and then changes to approximately N. 20° E., or essentially parallel to the Paloma fault, for the remaining distance in the Los Pinos area. The Montosa fault was followed southward for several miles beyond the limits of the present map where it is covered by flows of late Tertiary or Quaternary basalt.

Associated with both main thrusts are zones of shearing, bedding slip, and drag movements that suggest that displacement was not wholly confined to the two main lines of faulting. Approximately 1½ miles northeast of Sierra Montosa such move-

FIGURE 1. SILICIFIED FAULT BRECCIA OF SAIS QUARTZITE
Along Paloma thrust fault. Vertically dipping Pennsylvanian beds to east upturned by thrust from the west.

FIGURE 2. HOGBACK OF DES MOINES LIMESTONE
East of Montosa thrust along Highway 60.

FAULT BRECCIA AND LIMESTONE HOGBACK

FIGURE 1. VERTICAL STRATA ALONG MONTOSA THRUST
View looking north from Abo Pass showing vertically dipping beds along the fault. In right background the strata are dipping gently to the east.

FIGURE 2. SHOVE SYNCLINE
View looking south from Abo Pass showing small shove syncline just east of Montosa thrust fault.

STRUCTURES ASSOCIATED WITH THE MONTOSA THRUST

ments have been so pronounced that the Montosa fault consists of two distinct thrusts separated by an eighth of a mile or less and dipping westward with angles which locally exceeded 45°. The eastern fault lies entirely within the Permian rocks and east of Sierra Montosa. Here the faulting has its greatest throw, and lower beds of the Aqua Torres formation lie against strata believed to be near the middle of the Abo formation. At the north limit of Mt. Paloma the two faults merge and continue as one thrust of gradually decreasing magnitude to the south end of the mapped area, where in turn the Montosa and Paloma thrusts are joined and continue southward with very small throw.

R. H. Wilpolt, who assisted in the work as a graduate student and who has since worked in this area with the U. S. Geological Survey, states that he now thinks that the easternmost branch of the Montosa fault may be accounted for by drag of the main thrust, and that only one fault should be mapped east of Sierra Montosa (personal communication). The interpretation shown in section C-C′, Plate 7, is based on the outcrops northeast of Sierra Montosa which show the unmistakable thrust of pre-Cambrian over Permian in the westernmost slice, and in the easternmost slice the pronounced drag, silicified fault breccia, and difference in dips of the Permian strata on either side of the fault where the Aqua Torres is thrust over the Abo.

North of Highway 60 a normal fault seemingly branches from the Montosa thrust and extends northward for approximately 2 miles with a generally northward strike. Apparently it again joins the Montosa thrust. Except for its location the normal fault is not part of the Montosa fault and is interpreted as a break that accompanied the relaxation of the compressive stresses. Elsewhere, particularly south of Mt. Paloma, local drag on beds suggests that this post-thrusting normal faulting with downdropping on the west also occurred along the plane of the Montosa fault.

Except in the area chiefly north of Highway 60 and for approximately 2 miles south of the highway, thrusting along the Montosa fault does not reach the magnitude of that of the Paloma thrust. The greatest stratigraphic throw is where the Sais quartzite is against strata of the Virgil series. Although the stratigraphic throw is great the actual throw is far less, due to the position of the pre-Cambrian and Pennsylvanian contact when the faulting occurred. This can be demonstrated by extending the elevation of the Derry series—Blue Springs schist contact northeastward to the fault, where, at approximately the same elevation, strata near the base of the Virgil series are exposed on the downthrow side. North of Parker's ranch the throw is equal to the thickness of the Derry, Des Moines, and Missouri strata—approximately 1200 feet—and increases northward. South of the north limits of Mt. Paloma the throw decreases rapidly and approaches 100 feet where the fault was last definitely identified about 2 miles north of the southern limit of the map.

Folding associated with faulting.—The Pennsylvanian and Permian sediments, which normally dip at angles varying from 3° to 5°, have been dragged to vertical and in places completely overturned along the Montosa fault. Excellent exposures of this abrupt change in dip, as the fault is approached from the east, can be seen along Highway 60. The fault zone is easily recognized by the resistant ridge of silicified fault breccia in the Sais quartzite which crops out on both sides of the highway in ledges 15 to 20 feet in width, and standing 10 to 15 feet above the surrounding beds.

Immediately east of the fault breccia, a nearly vertical hogback in Pennsylvanian sediments forms a prominent ridge and is known locally as the "limestone dike" (Pl. 5, fig. 2). From this vertical dip the limestone beds flatten rapidly eastward and crop out along the highway, only 300 feet from the fault, showing the regional dip of 10°.

Another striking exposure of drag caused by the thrust faulting is in the railroad cuts at Abo Pass. The truncated ridges at the south end of the Manzano Mountains show vertical beds of limestone immediately east of the Montosa fault; 400 feet farther east the limestone resumes the normal regional dip of 10° (Pl. 6, fig. 1).

In many places the thrusting of the pre-Cambrian formations over the limestone has resulted in small crumplings. A small shove-syncline just east of the railroad cut at Abo Pass is shown in Figure 2 of Plate 6.

Strata between the Montosa and Paloma thrusts have the attitude of a part of an overturned anticline. (*See* Plate 7, sections C-C′ to J-J′.) Extension of the strata westward beyond the Paloma fault suggests that the thrusting developed from the rupture of an anticline and that the Montosa fault was probably the first to form. Its position and the structure between the two faults strengthen the probability that the Montosa thrust consists of imbricate slices which developed before the main thrusting along the Paloma fault. If so the junction of the faults would be expected and would explain the apparent absence of both faults at the southern margin of the area studied.

Cross faulting and shearing.—Numerous small cross faults occur throughout the entire area. These rarely exceed 3–4 feet in throw and doubtless represent local adjustments to stresses caused by the major thrusting. There are also innumerable small shear zones approximating parallelism which the regional dips of the formations and the angles of the Montosa and Paloma thrust planes. The shearing is especially prominent in outcrops of the slate and siltstone of the Blue Springs schist. Many thick zones have been so completely recrystallized that they are now almost entirely sericite. Thinner zones of schist have developed in interbedded lenses of argillaceous quartzite and in zones between massive rhyolite flows.

Classification of the thrust faults.—The westward dips of the Montosa and Paloma thrusts at angles between 40° and 55°—only slightly steeper than the regionally westward-dipping pre-Cambrian sediments—place the faults in the intermediate zone between low-angle overthrusts and high-angle reverse types.

The fault planes show some evidence of steepening near the present surface outcrops. Silicified breccia in many places appears to truncate the bedding of the Sais and White Ridge quartzites although the recognition of true bedding planes in the very completely brecciated and silicified zones is extremely difficult.

Only in a few outcrops are the faults exposed in vertical sections of any extent. The best exposures are in the railroad cuts at Abo Pass and in the railroad quarries south of the pass. Zones averaging 100 feet vertically and from 40 to 60 feet horizontally are exposed across the strike of the Montosa and Paloma thrusts. The structure is complicated in these outcrops by much contortion and by numerous shear planes that make up the fault zones. These shearing directions alternately break across and follow bedding planes in the quartzite formations. Drag folds are de-

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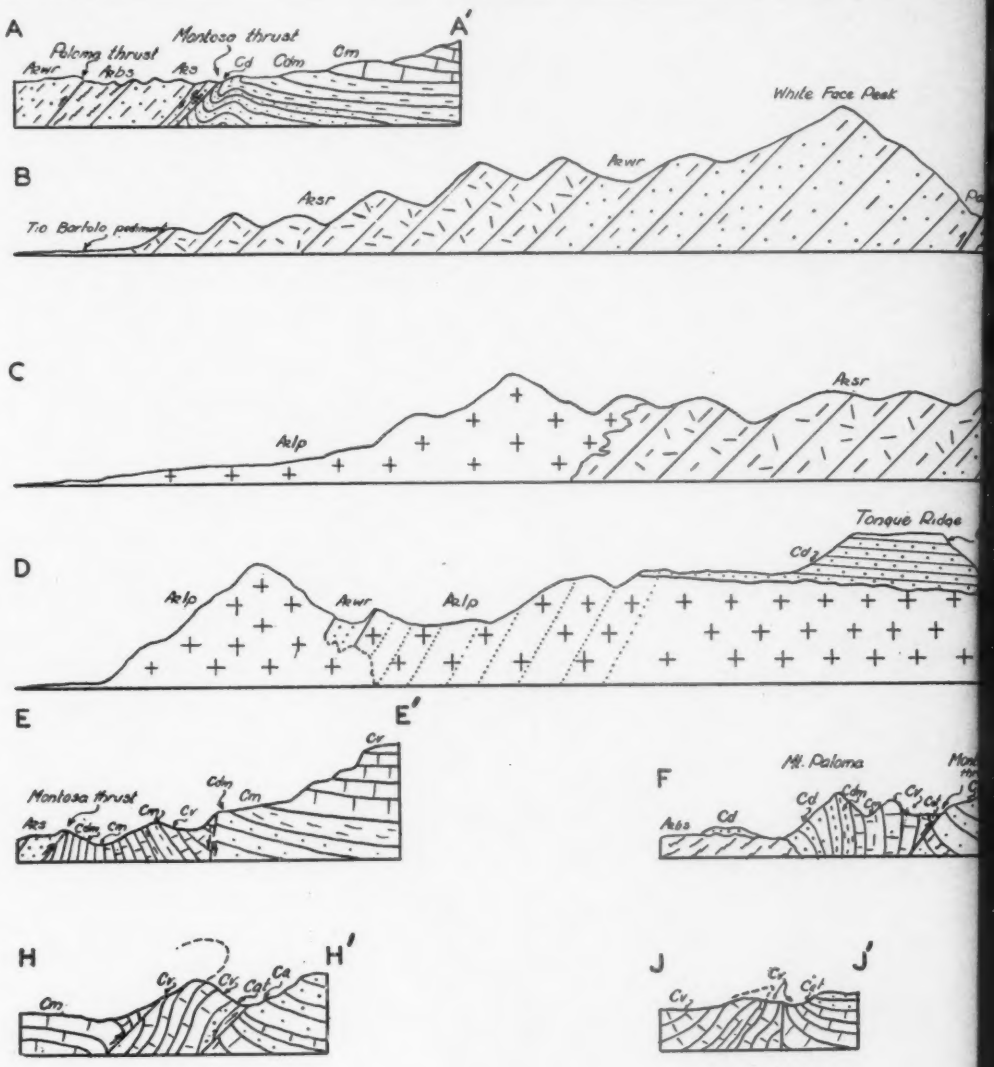
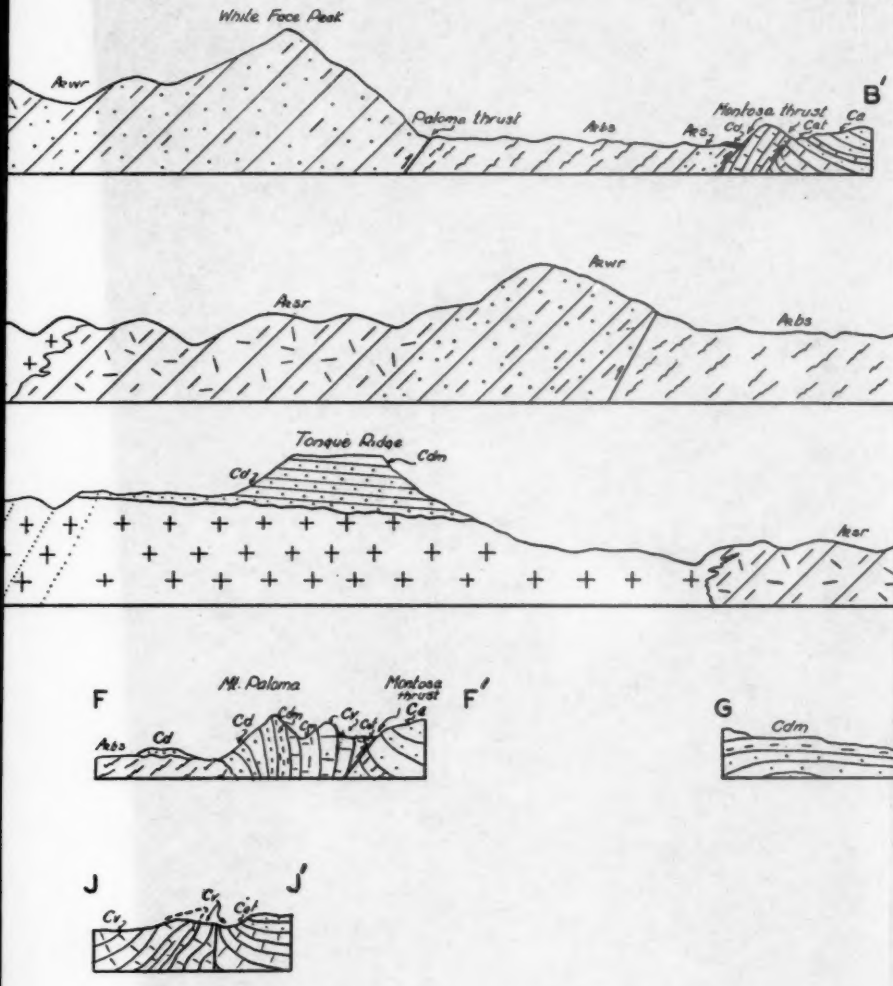
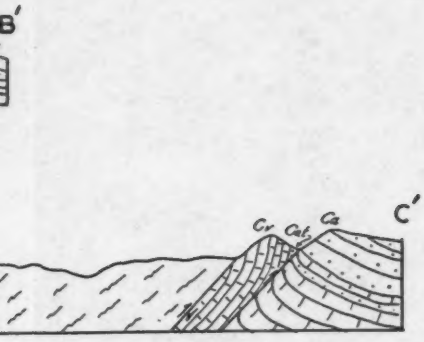


STRUCTURE SECTIONS ACRO



STRUCTURE SECTIONS ACROSS THE LOS PINOS MOUNTAINS, NEW MEXICO


Cv
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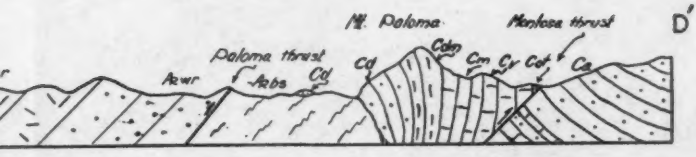
Mt. Paloma
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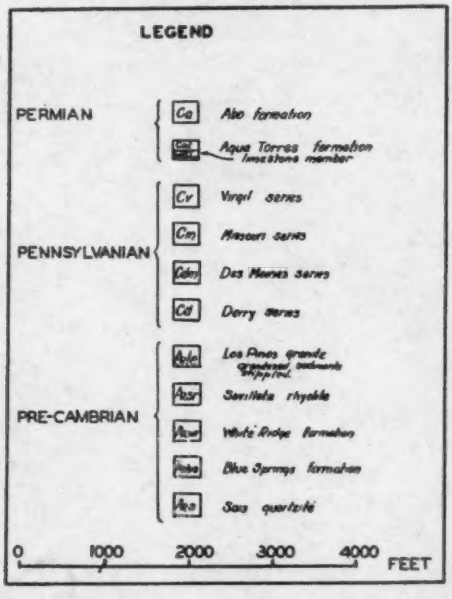
LEGEND
PERMIAN
Ca
Abo formation
Aqua Torres formation limestone member
PENNSYLVANIAN
Cv
Virgil series
Cm
Missouri series
Cdm
Des Moines series
Cd
Derry series
PRE-CAMBRIAN
Apbs
Los Pinos grande conglomerate, carbonate clipped
Apsr
Sandiola rhyolite
Apwr
White Ridge formation
Apbs
Blue Springs formation
Apa
Sais quartzite
0
1000
2000
3000
4000
FEET

MEXICO

veloped which range in cross section up to 20 feet. Sericite schist lenses between massive beds of quartzite thicken in the crests and troughs and thin or pinch out on the limbs of the folds.

Except for the steeper dips, these faults resemble the low-angle thrusting described by Chamberlin and Miller (1918, p. 1–8). Because of the tendency to follow bedding planes they probably would fall in "flat reverse type" of Behre's (1935, p. 11–12) classification of bedding-plane faults as a special steep-angle case. The explanation which Rich (1934, p. 1589–1593) offers for the Pine Mountain fault of southeastern Kentucky seems especially applicable to the Los Pinos thrusting in spite of the difference in dip angles of the fault planes. Rich emphasizes the tendency of the breaking to follow bedding planes and attributes the low dips of the thrust to the presence of nearly horizontal layers of softer, more plastic shales. Where frictional resistance became great the fault plane rose across bedding to higher levels where it met another shaly bed and continued along it to the next oblique rise. This apparently is what happened in both the Montosa and Paloma thrust zones, where the abundance of shaly beds permitted a large number of bedding-plane movements.

Associated block faulting.—Small normal faults immediately southwest of the Los Pinos Range have tilted blocks formed by Pennsylvanian limestone cuestas. Brecciated zones occur along bedding planes in the limestone which dips gently southwest off the pre-Cambrian formations of the Los Pinos uplift. The zones are thoroughly silicified and are confined to triangular blocks which are bounded on two sides by normal faults of Basin and Range type. Breccias of the bedded zones, capping the cuestas, are continuous with similar silicified zones along the steeply dipping normal faults. The more extensive outcrops of the breccias parallel to the bedding proved a useful criterion for discovering the less evident, narrow breccia zones of the normal faults. The fault blocks are domed by gentle folding, and slickensides suggest that the breccia zones along the bedding were formed by movements of beds upward toward the crests of anticlines during initial folding, and by subsequent slipping of beds down dip. The silicification of the zones was probably accomplished during the Tertiary. These fault blocks have been previously described in detail (Stark, Norton, and Staatz, 1943, p. 48–55).

Age of the thrusting.—Certain aspects of the Montosa and Paloma faults—their position, attitude, direction of dip, and extent—are so similar to other faults associated with the southern Rocky Mountains that the possibility of development of such faults as a part of the Laramide orogeny follows as a natural consequence. Unfortunately the time of thrusting in the Los Pinos Mountains has not been precisely determined and must be considered to have occurred sometime within certain bounding limits.

At the south margin of the area is a basalt flow classified as Quaternary by Darton (1928, Pl. 17). This flow overlies the Paloma thrust south of the area mapped. The basalt also overlies a conglomerate which is exposed south of locality D30 (Pl. 1). In turn the conglomerate lies unconformably upon Permian strata.

The conglomerate is a deposit of former pediment gravel and consists of pebbles and cobbles ranging up to a foot in diameter but dominantly 3 to 4 inches in longest dimension. Fragments of Abo sandstone, Yeso limestone, gray monzonitic dike

rock, pre-Cambrian quartzite, and basalt are embedded in light-gray sandstone matrix. Although this conglomerate has not been traced into pediment gravels of known age, lithologically it is most like the Santa Fe formation (Denny, 1940, p. 87). According to Denny (1940, p. 93–94) the Santa Fe formation in this locality is of middle to upper Pliocene age, whereas to the north it is somewhat older.

The alluvial fan at locality D22 (near center east side, Pl. 1), although possibly not the stratigraphic equivalent of the Santa Fe formation, belongs to the same period of sedimentation. This is indicated by its position, its relationship to the present drainage, and its lithology. This fan must have been deposited soon after the faulting and prior to the development of the present physiography. Therefore, the thrust fault can be presumed to be older than the middle Pliocene. Obviously this does not delimit the time of thrusting, and data must be gathered elsewhere to aid in the solution of whether such faulting is Laramide in age. In the Sandia Mountains Ellis (1922, p. 36) reports that the Santa Fe formation rests upon truncated upturned Cretaceous beds. Such folding was accompanied by major north-south faulting in the range and is post Cretaceous and pre Santa Fe (late Miocene or early Pliocene in this latitude). Since the Sandia, Manzano, and Los Pinos mountains are disconnected parts of the same mountain mass, the thrusting in the Los Pinos area is probably generally equivalent in time to that in the Sandias and quite possible is part of the Laramide orogeny.

Mountain border fault.—The straight western escarpment of the Los Pinos Range, rising steeply above the Tio Bartolo pediment, suggests the possibility of a large normal fault that raised the mountains with respect to the Rio Grande Valley. Denny (1940, p. 96–99) believes such a fault exists on the basis of not only the western escarpment but also on the distribution of Santa Fe beds in the Valley.

Field evidence for a mountain border fault is suggested in the block-faulted region on the southwest flank of the Los Pinos Range, where one fault has a trend which suggests that it may have continued northward as the border fault of the range. If it does, the northward trace is now buried beneath the pediment gravels. Also the proximity of Yeso beds, in Arroyo Aqua Torres, to the pre-Cambrian strongly supports the presence of a border fault.

SUMMARY OF GEOLOGIC HISTORY

Knowledge of the geologic history of the Los Pinos Mountains is restricted primarily to the events of the parts of two eras—the pre-Cambrian and the late Paleozoic. The conditions during other great units of time are unknown or at best can be only inferred. Such a history as can be postulated, however, is here given in chronologic sequence.

Pre-Cambrian

(1) Deposition of an excess of 8000 feet of marine sediments, namely Sais sands (quartzite), Blue Springs muds (schist), and White Ridge sands (quartzite). Consolidation, silicification of the sands, and uplifting unaccompanied by folding.

(2) Extrusion of more than 4500 feet of rhyolite flows upon the eroded sediments beneath. Also extrusions and intrusions of basic igneous rock.

(3) Tilting of strata toward the west to an angle approaching 40°, and accompanying dynamic metamorphism.

(4) Intrusions of the Los Pinos and Priest granites, and the accompanying granitization and metamorphism of the sediments.

Paleozoic

(5) Extensive erosion.

(6) Deposition of Pennsylvanian marine sediments in rhythmic cycles.

(7) Emergence and deposition of lower Permian (Aqua Torres) sediments, followed by submergence and deposition of remainder of Aqua Torres formation.

(8) Emergence and erosion followed by deposition of Abo terrestrial beds. Then submergence during deposition of the Yeso and younger Permian sediments.

Mesozoic and Cenozoic

(9) Thrust faulting and accompanying doming over center of Los Pinos Range, probably associated with the Laramide orogeny.

(10) Accumulation of Tertiary pediment gravels and intrusion of andesite, etc.

(11) Normal faulting in southwest and west portions of the range and elevation of western section of the range as a block.

(12) Extrusion of basalt and andesitic lavas presumably during the Quaternary.

MEASURED STRATIGRAPHIC SECTIONS

Sections of Derry series exposed in Turret Mesa (locality D25)

	Thickness (feet)
Des Moines series	
43. Limestone, dark gray, dense, earthy texture, slabby bedding in lower 7 feet, granular and coarse-grained in middle 20 feet, fine-grained and massive in upper 15 feet, *Dielasma bovidens, Composita ovata, C. subtilita, Spirifer sp.*	42
42. Limestone, light gray, weathers buff, bedded in 1–2 foot beds, forms a prominent cliff	40
41. Covered interval	7
40. Limestone, dark gray finely crystalline, massive to thinly but irregularly bedded, locally bedding is slabby; nodules in lower part, upper part cherty in veinlets and coatings on joint faces. Very fossiliferous in lower part, particularly fenestellid bryozoans and small brachiopods, forms a prominent cliff	25
Derry series	
39. Covered interval, underlain by thin, gray, fine-grained fossiliferous limestones, gray shales, and gray coarse sandstone beds	25
38. Sandstone, olive drab, micaceous, thin-bedded and cross-bedded	5
37. Covered interval—underlain by gray limestone and shales	30
36. Limestone, gray, fossiliferous, thin-bedded	1
35. Covered interval	5
34. Sandstone, light gray, locally conglomeratic, otherwise coarse-grained, grains chiefly granule size, angular and composed of quartz with numerous large flakes of muscovite, prominently cross-bedded. Foreset beds 5 feet thick, fragments of crinoids at top	5
33. Limestone, dark gray, very fine-grained, weathers to somewhat lighter color and smooth surface upon which fine laminations are noted	7
32. Sandstone, light gray, coarse-grained, chiefly composed of angular quartz fragments, large muscovite flakes, and brachiopods and crinoids	2
31. Limestone, dark gray, weathers to light-gray, smooth surface	2
30. Sandstone, light gray, composed chiefly of large quartz grains, cross-bedded, very fossiliferous; *Composita subtilita, Spirifer rockymontanus, Echinoconchus semipunctatus*	10

	Thickness (feet)
29. Limestone, light gray, weathers to dark gray brown, fine-grained to granular, extremely fossiliferous, composed almost entirely of fossil fragments, particularly spirifers and crinoid stems. Upper 5 feet less granular and less fossiliferous. *Neospirifer latus, Spirifer sp., Composita ovata, C. subtilita, Dielasma bovidens*...	9
28. Shale, gray, thinly bedded, weathers to a cinderlike surface	5
27. Sandstone, light gray, coarse-grained	2
26. Limestone, light gray, weathers to brown gray, finely crystalline, somewhat granular, checked and slightly solution-pitted, contains crinoids and a few brachiopods.	7
25. Sandstone, light gray, conglomeratic near top, contains 1–2-inch pebbles, lower portion coarse gray grit with large mica flakes, conglomeratic portion grades into limestone above	45
24. Limestone, dark gray, dense, weathers to light-gray smooth surface showing fine laminations	5
23. Conglomerate, light gray, composed chiefly of quartz pebbles	5
22. Sandstone, light gray to olive drab, thinly laminated but forms a massive bed, micaceous, becomes a limestone in lower portion	1½
21. Sandstone, light gray, coarse-grained, locally conglomeratic, composed of angular quartz grains 2–10 mm. in diameter, cross-bedded, bedded in 1–2-foot layers. Conglomerate zone 5 feet thick 80 feet above base, forms prominent cliff	105
20. Covered interval—underlain by thin-bedded sandstone	45
19. Sandstone, olive drab, weathers dark brown, alternately thinly and massively bedded, micaceous, coarse-grained	40
18. Sandstone, brown gray, coarse-grained, micaceous, massive, in lower 5 feet, cross-bedded, thin-bedded	30
17. Sandstone, light gray, composed of quartz pebbles and large muscovite flakes	10
16. Conglomerate, light gray, composed of small quartz pebbles, massive, cross-bedded, 3 feet of thin-bedded sandstone in central portion	10
15. Shale, dark gray, weathers to light gray cinderlike surface, thin-bedded, well-cemented, silty	5
14. Sandstone, light gray, coarse-grained, composed of quartz grains, weathers to rounded surface	3
13. Limestone, gray, weathers to brown irregular surface, fine-grained, dense, very fossiliferous, *Dielasama bovidens, Marginifera lasallensis*	1
12. Sandstone, gray to very light gray, composed of coarse angular quartz grains, massive, weathers to granular surface	10
11. Sandstone, gray brown to olive drab, coarse-grained	5
10. Limestone, gray brown, coarsely granular, weathers to sandy, gray surface, cross-bedded, very fossiliferous, bedded in 1-foot beds, but weathers to thinner slabs. In upper 3 feet it becomes very sandy and grades into sandstone above	20
9. Limestone, olive drab, arenaceous, coarsely crystalline, poorly and thinly bedded, breaks into irregular nodular masses, very fossiliferous	2
8. Shale, calcareous, locally thin-bedded limestone, grades upward from base into a thin-bedded, micaceous, olive-drab sandy shale	8
7. Limestone, brown, weathers to a gray-brown surface, very arenaceous, massive and irregularly bedded, breaks into slabs upon weathering, coarse-grained and fossiliferous 2 feet above base	3
6. Shale, black to dark gray, weathers to brown gray, very fissile, carbonaceous, contains many small brachiopods	17
5. Shale, gray, weathers light gray	4
4. Sandstone, red brown, quartzose	2
3. Quartzite, white, grades upward into red-brown sandstone, locally conglomeratic.	2
2. Conglomerate, white to pinkish gray, consists of quartz pebbles, angular to subround, varying from ¼–1-inch in diameter, locally quartzitic. Granite pebbles rare, but feldspar present in sandy portions, fingers into weathered pre-Cambrian granite	2–5
1. Pre-Cambrian granite	

Section of Des Moines series (partial) and Derry sesies Exposed in Tongue Ridge (Locality D39)

	Thickness (feet)
Des *Moines series*	
32. Limestone, light gray, nodular, massive in central part, locally grades from massive to slabby, cherty, forms a prominent cliff, *Fusulina euryteines*	90+
31. Limestone, light gray, weathers gray buff, earthy, locally shaly, somewhat nodular near center, fossiliferous	35
30. Limestone, gray, coarse-grained composed of fossil fragments	5
29. Sandstone, olive drab, fine-grained, calcareous, mottled, nodular, micaceous	5

	Thickness (feet)
28. Limestone, grayish brown, arenaceous, weathers olive drab, contains large productids, becomes granular and crinoidal near top, emits a petroliferous odor when struck	5
27. Limestone, light gray, nodular, irregularly bedded in 6-inch to 1-foot layers, *Fusulina taoensis, Fusulina* sp.	22
26. Limestone, light gray, consists of small, (1–2-inch), irregular nodules in a shale matrix, grades upward into massive limestone	10
25. Limestone, gray, subcrystalline, bedded in layers 4 feet thick and somewhat cherty	4
24. Sandstone, light gray, coarse-grained, cross-bedded	7
23. Limestone, medium gray, subcrystalline, weathers brown, very fossiliferous, *Fusulina socorroensis, Fusulina* sp.	2
22. Limestone, gray, consists of nodules of dense, fine-grained, irregularly shaped nodules in a gray shale matrix, *Fusulina socorroensis, Fusulina* sp.	7
Derry series	
21. Shale, gray, silty, thinly bedded paper shale, contains plant fragments	5
20. Sandstone, light gray, very coarse, cross-bedded, near top becomes conglomeratic	22
19. Limestone, brown gray, mottled, finely crystalline, beds 6 inches–1 foot thick, grades upward into sandstone above	7
18. Sandstone, olive drab, micaceous, thinly bedded, contains scattered plant remains in lower 15 feet; grades upward into a coarse-grained, cross-bedded, light-gray sandstone and then near top is again an olive-drab micaceous sandstone	80
17. Limestone, gray, dense, finely crystalline, massive, very fossiliferous, weathers to to smooth brown surface. *Marginifera lasallensis, Wellerella* sp.	5
16. Shale, olive drab, (drak gray near center) micaceous, silty	15
15. Sandstone, olive drab, micaceous, massive	1
14. Shale, olive drab, micaceous, sandy, thin-bedded	5
13. Sandstone, light gray, weathers gray buff, quartzose, cross-bedded, massive	5
12. Shale, gray, micaceous, silty, thin-bedded, grades into sandstone zones	20
11. Limestone, brown gray, locally black, thin-bedded, contains shale layers, very fossiliferous. *Spirifer occidentalis, Composita subtilita*	1
10. Shale, dark gray, paper shale, micaceous, silty, contains a few thin bands of ironstone concretions	10
9. Sandstone, light gray, very coarse-grained, weathers buff, cross-bedded, in 1–2-foot beds	20
8. Limestone, dark gray, weathers brown, extremely granular, consists almost entirely of fossil fragments	5±
7. Sandstone, light gray, very coarse-grained, mottled by pyrolusite fragments, weathers brown, in 2-foot beds	15
6. Limestone, light gray, finely crystalline, mottled, grades upward into brown-gray coarsely granular limestone containing much quartz and feldspar, weathers brown, *Marginifera lasallensis, Neospirifer latus*	15
5. Shale, light gray, thinly bedded, sandy, weathers red along fractures	4
4. Sandstone, gray, fine-grained, streaked, dense, quartzose, weathers red along joints	1½
3. Sandstone, white, grades upward into a gray shale, massive near base	4
2. Sandstone, light gray, weathers brown red, slabby, quartzose	20
1. Conglomerate, light gray, quartzitic, quartz pebbles	15
Unconformity	
Blue Springs schist	

Section of Des Moines series exposed in Abo Pass railroad cut (locality D27)

	Thickness (feet)
Missouri series	
18. Limestone, medium gray, weathers to light-gray smooth surface, finely crystalline, beds 10 inches thick	5
17. Covered interval	15
Des Moines series	
16. Sandstone, light gray, massive, coarsely granular, arkosic, weathers to smooth rounded surfaces	5
15. Limestone, medium gray, mottled, weathers light gray, irregularly bedded in layers 2–5 feet thick, occasional shale layer present, contains flint nodules in lower 35 feet, fossiliferous, *Composita subtilita, Echinoconchus semipunctatus, Dictyoclostus portlockianus, Neospirifer triplicatus*	90
14. Shale, medium gray, micaceous, thinly bedded, contains an irregularly shaped 3-inch limestone bed in center	1

	Thickness (feet)
13. Limestone, medium gray, finely crystalline, massive, *Composita*	1
12. Covered interval, underlain by gray, micaceous, silty shale	20
11. Limestone, gray, coarsely crystalline, massive	1
10. Shale, dark gray, paper shale, silty, micaceous, gypsiferous, grades upward into light-gray shale which contains calcareous nodules and then a nodular limestone	18
9. Limestone, light gray, weathers buff, coarsely crystalline, massive, *Composita argentea, C. subtilita, Composita* sp., *Dielasma bovidens, Echinoconchus semipunctatus, Dictyoclostus portlockianus*	90
8. Limestone, light gray, weathers buff, finely crystalline, irregular beds 2–5 feet thick, cherty along joint faces, some cherty portions 95 feet above base, *Fusulina socorroensis, F. rockymontana*	205
7. Limestone, medium gray, locally cherty near center, forms prominent ridge	50±
Derry series	
6. Shale, gray, dense, calcareous and partly silicified, weathers into olive-drab splintery masses	1
5. Sandstone, light gray coarse-grained bedded in 2-inch layers, cross-bedded, micaceous, calcareous, upper 5 feet in one massive bed	20
4. Limestone, dark gray, blocky, bedded in 8-inch layers, weathers to a smooth surface	3
3. Sandstone, gray, coarse-grained, cross-bedded	10
2. Limestone, dark gray, finely crystalline, checked with calcite veinlets, weathers to smooth surface	10
1. Sandstone, olive drab, coarse-grained, micaceous; cut by Paloma thrust fault which places Blue Springs schist in contact with the sandstone	15

Section of Virgil and Missouri strata in Sand Canyon beginning at Dripping Springs (extends from Locality D20 northward to Abo Pass railroad cut)

	Thickness (feet)
Aqua Torres formation	
33. Shale, red brown, silty, contains gray limestone nodules	
Virgil series	
32. Limestone, gray, finely crystalline, mottled on smooth surface, bedded in layers 1–2 feet thick, contains irregular masses of chert which near upper surface of bed is green, *Triticites plummeri* var. Dunbar and Condra	55
31. Limestone, gray, finely crystalline, mottled on smooth surface, in beds 1–2 feet thick, *Triticites ventricosus, T. kellyensis* var. Needham, *Marginifera wabashensis, Neospirifer* sp., *Dictyoclostus portlockianus, Composita* sp., *C. argentea, Squamularia perplexa*	25
30. Shale, calcareous, locally an argillaceous limestone	5
29. Limestone, light gray, nodular, locally interbedded with fossiliferous calcareous shale, *Composita argentea, Dictyoclostus portlockianus, Marginifera wabashensis, Neospirifer latus*	10
28. Limestone, light gray, very nodular in zones, locally contains veins of chert along joint planes, bedded in 6-inch to 1-foot layers	8
27. Covered interval	5
26. Limestone, light gray, subcrystalline to crystalline, becomes cherty 15 feet above base, forms a massive cliff; fusulines abundant above lower 15 feet, *Triticites moorei, T. ventricosus* var. *sacramentoensis, Neospirifer* sp., *Marginifera wabashensis, Squamularia perplexa, Composita subtilita*	25
25. Covered interval	22
Missouri series	
24. Limestone, light gray, weathers dark gray, finely crystalline, bedded in 2-foot layers, very fossiliferous in zones, *Composita* sp., *Marginifera wabashensis, Linoproductus* sp., *Squamularia perplexa*	15
23. Sandstone, yellow, thin-bedded	2
22. Limestone, dark gray, weathers brown, finely crystalline breaks with irregular fracture, solution pitted, bedded in 2–3-foot layers, *Composita subtilita*	10
21. Sandstone, yellow buff, massive, cross-bedded in thin beds	12
20. Shale, olive drab, micaceous, sandy, thinly bedded	10
19. Shale, black, weathers light gray, thinly bedded	3
18. Limestone, gray, nodular, massive, contains phosphatic pellets near top	6
17. Limestone, medium gray, finely crystalline, nodular and granular, massive, *Fusulina*-bearing zone near middle, *Triticites nebraskensis, T. cullomensis* var. *pygmaeus*	6
16. Shale, dark gray, thin-bedded	10+
15. Limestone, dark gray, finely crystalline, arenaceous	2

	Thickness (feet)
14. Shale, gray, silty, contains plant fragments, breaks into small rounded fragments	7
13. Sandstone, yellow buff, darker on weathered surface, varies from massive to thin-bedded, cross-bedded, micaceous, locally shaly, contains a few plant fragments	60
12. Limestone, light gray, weathers buff, crystalline, bedded in 1–2-foot layers, irregularly bedded, contains several nodular fossiliferous shaly zones near center, weathered upper surface suggests an edgewise conglomerate	25
11. Covered interval	15
10. Sandstone, light gray, weathers yellow	2
9. Shale, black to dark gray, thin-bedded, contains calcareous ironstone concretions 1 by 6 inches and limestone beds 1 inch to 1 foot thick, *Myalina* abundant	55
8. Shale, olive drab, sandy, becomes a sandstone near center, then a dark shale with veinlets of gypsum and an olive-drab sandstone near top	15
7. Sandstone, olive drab, micaceous, massive, cross-bedded	10
6. Shale, dark gray, thin-bedded, locally blocky, contains calcareous ironstone concretions, ostracods, and fragments of leaves and stems	15
5. Covered interval	40
4. Limestone, medium gray, weathers light gray, finely crystalline, bedded in 10-inch layers	5
3. Covered interval	15
Des Moines series	
2. Sandstone, light gray, coarse-grained, massive arkosic etc. (*See* No. 16, section Abo Pass railroad cut Locality D27.)	5
1. Limestone, medium gray, weathers light gray, massive	

Section of Virgil and Missouri series at south end of Los Pinos Mts. (*Section extends northward from Locality D30*)

	Thickness (feet)
Aqua Torres formation	
33. Limestone, dark gray, somewhat nodular and brecciated, contains much flint and jasper in bands and irregular masses, fossils commonly jasperoid, *Schwagerina emaciata, Dictyoclostus portlockianus, D. americanus, Neospirifer triplicatus*	20+
Covered interval	40
Virgil series	
32. Limestone, light gray, dense, slightly cherty, nodular in lower portion, bedded in 3–5-foot layers, forms prominent cuesta. *Triticites ventricosus, Marginifera wabasi ensis, Neospirifer triplicatus, Composita argentea, Dielasma* sp.	125
Missouri series	
31. Limestone, light gray, dense, massive, poorly exposed, *Triticites wellsi, T. secalius* var. *oryziformis* Newell, *T. nebraskensis*	40
30. Limestone, dark gray, weathers to light gray, smooth surface, *Triticites nebraskensis, Marginifera wabashensis, Neospirifer triplicatus, Composita* sp.	15
29. Shale, gray, very calcareous, granular and nodular, grades downward into a limestone	1
28. Limestone, dark gray, weathers light gray	5
27. Sandstone, olive drab, micaceous, massive but very finely laminated, grades downward into plant-bearing shale	5
26. Shale, gray, silty, micaceous, near base contains thin ironstone concretions with stems of plants on their surfaces	15
25. Limestone, dark gray, weathers dark brown, finely crystalline, breaks with conchoidal fracture, near base becomes more nodular and massive	10
24. Sandstone, gray, weathers brown gray, fine-grained, cross-bedded, grades into massive sandstone below	20
23. Sandstone, gray, weathers brown, thin-bedded, micaceous, at base becomes a finely laminated sandstone weathering a deep brown and breaking off in blocky fragments	12
22. Covered interval	5
21. Sandstone, dark gray, weathers deep brown, calcareous, weathers into slabby fragments, contains plant fragments, lower 2 feet is finely laminated and breaks in blocks	7
20. Shale, olive drab to gray, very sandy, micaceous, locally a thin-bedded sandstone stained with limonite, contains septarian concretions which reach a diameter of 4 feet	15±
19. Limestone, light gray, weathers buff, subcrystalline, locally flaggy	10
18. Sandstone, light gray, coarse-grained, grains nearly all quartz, well cemented, massive	6
17. Limestone, light gray, weathers buff, subcrystalline	12

	Thickness (feet)
16. Arkose, greenish gray, weathers purple, coarse-grained, poorly exposed	22
15. Limestone, light gray, weathers brown gray, finely crystalline, massive, locally nodular and cut by calcite veinlets, some chert along joint faces. *Dielasma bovidens, Composita elongata, C. ovita, C. subtilita, C. argentea, Linoproductus* sp.	30
14. Sandstone, light gray, very calcareous, grades upward into nodular, sandy limestone, grains chiefly quartz, very fossiliferous, grades downward into a dark-gray micaceous, fine-grained sandstone barren of fossils	3
13. Covered interval	30
12. Limestone, brown gray, weathers brown, coarsely granular, consists largely of fossil fragments particularly crinoid stems	3
11. Limestone, gray, weathers brown; the rock is so profusely fossiliferous that it appears conglomeratic, *Marginifera wabashensis* preponderant	1
10. Limestone, brown gray, coarsely granular, chiefly broken fossil fragments	2
9. Limestone, light gray, weathers buff, bedded in 1–3-foot layers, finely crystalline at base, near top oölitic	10
8. Covered interval	10
7. Limestone, light gray, weathers brown, very coarsely crystalline, contains much quartz and feldspar, very fossiliferous (chiefly fragments) *Neospirifer latus*	4
6. Sandstone, light gray, poorly cemented, nearly all quartz grains, somewhat micaceous, cross-bedded near base	30
5. Covered interval	5
4. Limestone, brown gray, weathers brown, very granular, largely fossil fragments, grades into finely crystalline limestone near center, *Neospirifer latus, Dielasma bovidens, Squamularia perplexa, Echinoconchus* sp., *Composita elongata*	15
Des Moines series	
3. Covered interval	2
2. Sandstone, green, micaceous, calcareous, fine-grained, thin-bedded at top massive near base	7
1. Limestone, dark gray, dense, slabby in lower part, granular and coarse in middle, blocky in upper 15 feet, *Fusulina sp.*	42

Section of Virgil and Missouri series along Highway 60 (Locality D9)

	Thickness (feet)
Aqua Torres formation	
24. Conglomerate, red brown, red limestone pebbles	3
Virgil series	
23. Limestone, medium gray, dense, breaks with conchoidal fracture, bedded in 2-foot layers, locally nodular and mottled near top, some chert in central portion, *Campophylum* sp., *Composita subtilita, Dictyoclostus portlockianus, Triticites ventricosus, T. plummeri* var. Dunbar and Condra	50+
22. Covered interval	30
21. Limestone, gray, dense, massive poorly exposed	10
20. Covered interval	10
19. Limestone, gray, apparently in one massive bed	4
18. Covered interval	25+
Missouri series	
17. Limestone, medium gray, dense, massive, contains small veinlets and blebs of calcite, *Composita*	25+
16. Shale, gray, alternating with gray limestone beds 3–6 inches thick, shale contains crinoid stems, fenestellid Bryozoa, and fragments of brachiopods, *Composita subtilita, Marginifera wabashensis*	4
15. Limestone, gray to brown gray, weathers to light-gray, smooth surface, breaks with conchoidal fracture, finely crystalline, massive *Triticites nebraskensis*	8
14. Sandstone, yellow to olive drab, micaceous, contains plant fragments, grades into limestone above	2
13. Shale, gray to olive drab, thinly bedded, micaceous plant bearing, grades into sandstone above	20
12. Limestone, gray, dense, *Triticites* sp.	3
11. Shale, gray, contains nodules of limestone	3
10. Limestone, dark gray, massive	3
9. Shale, gray, somewhat silty, irregularly bedded	3
8. Sandstone, gray to olive drab, micaceous, thinly bedded	4
7. Shale, dark gray to olive drab, weathers to cinderlike surface, silty, micaceous, contains plant fragments	10
6. Limestone, gray, somewhat nodular, locally shaly, *Triticites wellsi, T. nebraskensis*	6
Fault	

	Thickness (feet)
Virgil series	
5. Shale, gray, silty	3
4. Limestone, gray, very arenaceous	3
3. Shale, gray to olive drab, micaceous, contains plant fragments and a few brachiopods	30
2. Limestone, dark gray, weathers brown, cut by thin calcite veinlets	2
1. Shale, dark gray, thinly bedded, contains a profusion of *Derbya crassus*	25′

Section of Aqua Torres formation exposed along road to Parker's ranch about three quarters of a mile south of Highway 60 (Locality D15)

	Thickness (feet)
Abo formation	
7. Sandstone, hematite red, slabby, coarsely granular	
Aqua Torres formation	
6. Limestone, dark gray, weathers brown gray, massive, subcrystalline, mottled, contains fossils replaced by jasper. *Schwagerina emaciata* var. *jarillensis, Triticites sp.*	40±
5. Shale, red, poorly exposed	15
4. Conglomerate, brown red weathers to large round masses, arkosic, cross-bedded, fragments chiefly less than ½-inch in diameter, grades upward into a pink-gray arkose containing plant fragments	40±
3. Marl, white, very calcareous, uncemented	2–5
2. Conglomerate, brown red, calcareous, pebbles red and gray limestone, and quartz, well cemented	3
Virgil series	
1. Limestone, gray massive, mottled, *Triticites ventricosus*	

Section of Aqua Torres formation at south end of Los Pinos Range (Locality D41)

	Thickness (feet)
Aqua Torres formation	
11. Limestone, light gray, subcrystalline, massive, somewhat nodular, jasperoid, fossils, *Schwagerina emaciata, Dictyoclostus portlockianus, Neospirifer triplicatus*	5
10. Shale, grayish white, thin-bedded, has reddish tinge on weathered surface, poorly exposed	10
9. Limestone, gray, blocky, massive, subcrystalline, somewhat nodular	2–4
8. Covered interval apparently underlain by red shale	20
7. Limestone, light gray, nodular, blocky	1
6. Shale, red, becomes grayish near top, consists of small limestone nodules embedded in a shale matrix	3
5. Limestone, light gray, nodular, rather irregular	1
4. Sandstone, red, slabby	5–10
3. Sandstone, gray, weathers reddish, medium-grained, poorly cemented, micaceous, locally contains a 1-foot nodular limestone	25
2. Sandstone, red, thinly bedded and slabby	15
Virgil formation	
1. Limestone, gray, massive, irregularly bedded.	

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CONTENTS

	PAGES
Abstracts of papers presented at the meeting in Chicago, December 26–28, 1946 (Geological Society, Mineralogical Society, Paleontological Society, and Society of Vertebrate Paleontology)	1173–1248
Abstracts of papers presented at meeting in Berkeley, April 19–20, 1946	
Cordilleran Section of Geological Society	1249–1259
Pacific Coast Branch of Paleontological Society	1260–1262
Abstracts of papers presented at meetings of Section E, American Association for the Advancement of Science	
St. Louis, Missouri, meeting, March 27–29, 1946	1263–1276
Cambridge, Massachusetts, meeting, December 30–31, 1946	1277–1288
Index to Volume 57 (July–December)	1289–1302

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PAPERS IN PRESS FOR FORTHCOMING ISSUES

KOOLAU BASALT SERIES, OAHU, HAWAII. By C. K. Wentworth and Horace Winchell

HONOLULU SERIES, OAHU, HAWAII. By Horace Winchell

TOPOGRAPHY OF THE GULF OF MAINE—FIELD SEASON OF 1940. By Harold W. Murray

SOLUTION SCULPTURING IN LIMESTONE PEBBLES. By H. W. Scott

STRATIGRAPHY OF THE UPPER CAMBRIAN, LLANO UPLIFT, TEXAS. By Josiah Bridge, V. E. Barnes, and P. E. Cloud, Jr.

FAULT PROBLEMS IN FAULT PLANES. By R. H. Beckwith

ZION NATIONAL MONUMENT, UTAH. By Herbert E. Gregory and Norman C. Williams

DEVONIAN ROCKS OF CENTRAL TEXAS. By V. E. Barnes, Preston E. Cloud, Jr., and L. E. Warren

BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA
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ABSTRACTS OF PAPERS PRESENTED AT THE DECEMBER MEETING IN CHICAGO, DECEMBER 26–28, 1946

SOME U. S. BOEHMITE LOCALITIES*

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The only boehmite locality in the United States listed in the Seventh Edition of Dana's Mineralogy is incorrectly reported to be the Linwood-Barton district, Georgia. More than 200 samples of bauxite and clay from Alabama and Georgia, including some from Linwood, Bartow County, Georgia, were examined by X-ray and optical methods and found to contain gibbsite but no boehmite.

Investigation of alumina hydrates of the United States was started with a grant from The Geological Society of America in 1941 and continued during 1942 to 1946 in connection with the high-alumina clay project of the Geological Survey, U. S. Department of the Interior. The boehmite occurrences reported by H. S. McQueen near Swiss and Stolpe, Gasconade County, Missouri, associated with flint and diaspore clays of Pennsylvanian age, were verified, and the following new localities for boehmite were established: associated with Paleocene gibbsite in black pisolites on the Townsend 40 property, about 2 miles east of Bauxite and near Berger, Pulaski County, Arkansas; as oöliths in Pennsylvanian flint clay at the Burnt House mine, Olive Hill, Carter County, Kentucky; with kaolinite in the Puget shales of Eocene age at Durham, Kanaskat, and Kummer, King County, Washington; with diaspore at the Cle Elum iron deposit, Kittitas County, Washington; with gibbsite in oöliths associated with Paleocene clay at Alberhill, Riverside County, California.

ORIGIN OF THE BENSON CLAY DEPOSIT, LATAH COUNTY, IDAHO*

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The Benson clay deposit was formed by weathering, and not as a result of hydrothermal activity as has been suggested in some reports. Weathering started at the surface and penetrated down to 100 feet or more. In the series of thin sections studied, no feldspars or biotite are present in rocks collected near the surface, and kaolinite, muscovite, and quartz are the chief minerals. At a depth of 52 feet below the surface fresh feldspars are first observed as well as yellow iron oxides that were deposited by descending solutions. At a depth of 66 feet areas of relict green biotite within large sheets of kaolinite containing rutile needles are evidence that this kaolinite was formed by the alteration of biotite. The amounts of fresh feldspars and biotite increase progressively with depth indicating that weathering decreases in intensity with depth. Furthermore, no mineral having the optical properties of dickite was observed.

Irregularity of residual clays of the Benson type derived from silicic intrusive rocks or their metamorphic equivalents depends on: (1) nature of the parent rock; (2) local structures controlling permeability; (3) duration of the weathering interval; (4) irregularity of erosion prior to, contemporaneous with, and subsequent to the weathering.

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DIAGENESIS OF THE CLINTON HEMATITIC ORES OF NEW YORK

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Quantitative microscopic analyses of the Clinton iron ores of New York and associated rocks in the form of thin sections reveal a succession of introductions and replacements which were responsible for the formation of the ore. The iron was introduced by surface waters shortly after deposition and replaced a series of sedimentary minerals, chiefly carbonates, as part of the diagenesis of the rock. For this, the expression *diagenesis replacement* is here proposed.

Use was made of stratigraphic diagrams recently developed, employing the concept of "microlithologies." These show that these ores were originally largely limestones which were replaced by iron compounds, now largely hematite, provided certain essential conditions prevailed and the clay content was less than 10 per cent by weight. The oölitic coatings consist of hematite and chamosite in alternating thin layers, onion fashion. The "fossil" ores are the result of the partial replacement of the carbonate and the subsequent oölitic coatings. These replaced fossils act as nuclei.

The Clinton ores are lenticular and possess little or no stratigraphic significance; they represent similar lithologic conditions.

DRAINAGE DIVERSION IN THE NORTHERN ROCKY MOUNTAINS OF EAST-CENTRAL IDAHO

ALFRED L. ANDERSON

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Piracy and large-scale faulting have had an important role in disrupting a Tertiary drainage system and in fixing the pattern of existing stream systems in the Northern Rocky Mountains of east-central Idaho. The mountains here are uplands of the dissected plateau type which have in part been broken into block mountains with intervening basins like those in Utah and Nevada.

The northeast trend of the headwaters of Salmon River, its main tributaries, and the similar trend of Big Lost River and other parallel streams are indicative of an early drainage aligned in that direction. This inference is confirmed by the presence of wind gaps across the block mountains as prolongations of each stream. Reversal of the Salmon is suggested by barbed tributaries and elbows of capture. Accordingly, the early Tertiary drainage extended across the Continental Divide and perhaps to the Missouri River.

Diversion of Salmon River from its previous northeast course to the Snake River drainage on the opposite side of the State must have been brought about by headwater erosion of a west-flowing stream in late Tertiary time. Diversion of Lost River and other streams from their northeast courses into northwest-southeast structural basins resulted from block faulting in late Tertiary or early Quaternary time. By reason of these diversions the Continental Divide was shifted about 100 miles east of its location in late Tertiary time.

EPITHERMAL MINERALIZATION AT THE LAST CHANCE-HORNSILVER MINES, LAVA CREEK DISTRICT, BUTTE COUNTY, IDAHO

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The epithermal deposits in the Lava Creek district are confined to a zone of structural weakness in Tertiary volcanics which facilitated intrusion of Miocene magma and circulation of ore-bearing solutions. After widespread sericitization, chalcedonization, pyritization, and local aluminitization had initiated the first of two main stages of mineralization, pyrite, marcasite, sphalerite, wurtzite,

galena, and chalcedony were deposited from solutions whose flow was controlled by minor structural adjustments at the source and along the channelways. Following a more marked structural reopening a second assemblage consisting of minor and variable amounts of quartz, barite, pyrite, stannite, tetrahedrite, famatinite, enargite, klaprothite, chalcopyrite, aikinite, and dickite were added. Lack of equal permeability of fracture zones during mineralization resulted in considerable variation in substance of individual lodes. Those of present commercial interest contain a notable concentration of lead and zinc sulfides.

Characteristics of the mineralization indicate that the early solutions were alkalic and moderately hot, but with the formation of alunite they became and remained acidic and mostly below 135°C. Intimate associations of pyrite-marcasite and sphalerite-wurtzite afford evidence of a delicate balance between temperature and acidity with some fluctuations of one or the other and a gradual rise in temperature at the close of the stage. Colloform structures in the iron and zinc sulfides suggest colloidal phenomena. Solutions remained acid during the second stage of deposition but had a higher temperature than during the earlier stage.

QUATERNARY SEDIMENTS IN STEEP ROCK LAKE, ONTARIO

ERNST ANTEVS

The Corral, Globe, Arizona

After Seine River had been diverted, the three upper arms of the M-shaped Steep Rock Lake, 115 miles west of Port Arthur, Ontario, were dewatered by pumping in 1943–1944, and later the loose sediments have been partly removed for access to bodies of high-grade iron ore. The sediments thus exposed consist of glacial silts and clays, 100 feet thick (through repetition by sliding, up to 200 feet), and of overlying organic deposits, 5 to 10 feet. Samples of these latter, which may represent the entire age since the ice left the region, will be analyzed by William S. Benninghoff of Harvard.

The glacial sediments comprise five series, each beginning with an exceptionally thick varve (annual deposit). Series 1, which rests on till, is 50, and series 2 is 7 feet thick. They contain 600 and 130 normal glacial varves. Series 3 and 4, 15 and 7 feet thick, are composed largely of silt with clayey laminae which range from distinct to barely observable. While marked clay laminae are winter deposits and faint ones represent chilly spells during summer, many intermediate ones are puzzling. Series 5, 20 feet thick, consists of both typical varves and of such with faint clay laminae in the silty summer deposits. These sediments together represent well over a millennium.

Varved clay at near-by Atikokan shows that glacial Lake Agassiz spread there and reached the altitude of 1300 feet. Though varved clays occur at 1283 feet just south of Steep Rock Lake, the water level probably soon fell to the strikingly developed modern shore at 1263 feet.

Clays, moraines, and till overlying varved clays indicate slow retreat, halts, and readvances of the ice border. (Geological Society project.)

ORIGIN OF THE NEW YORK STATE FINGER LAKES

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The New York State Finger Lakes occupy narrow and deep rock basins which are partly filled with glacial debris. The northern ends of the rock basins lie near the escarpment of the Appalachian plateau, while the southern ends lie several tens of miles to the south and well within the area of the plateau. From the deepest part of the basin the rock floor ascends both north and south.

It is inferred that the basins of the Finger Lakes were excavated by the continental glaciers beneath a marginal zone of active ice, the width of which coincided approximately with the length of the deep rock valleys. It is postulated that other valleys not now occupied by Finger Lakes but partly filled by glacial debris were eroded under the same or a similar zone of active ice. Perhaps the deepest bed-

rock valleys represent the zone of concentrated erosion of several glacial stages or substages which elsewhere failed to coincide and therefore failed to produce the same striking features.

The effects of a marginal zone of active ice of the continental glacier appear to be reflected also in the dominance of local rock materials in the drift and the patchy distribution of old drifts.

SOME EXAMPLES OF THE DISTRIBUTION OF FLUORINE IN ROCKS

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New data of fluorine in rocks and thermal emanations are presented. They corroborate the earlier conclusions of E. S. Shepherd (1940) that fluorine is not an insignificant constituent of the Earth's crust; he thinks that about 0.04 per cent F is characteristic of plutonic rocks, that is lower in lavas, higher in alkaline rocks.

In the plutonic rocks of the (alkaline) Oslo province the average concentration of fluorine is 0.075 per cent (range 0.063–0.090). In basalts from Iceland the fluorine content ranges from 0.002 to 0.040, average 0.017 per cent F. In the Oslo kauaiites (formerly erroneously called essexites) the average is 0.070 per cent F.

In the Oslo plutonics fluorine shows no relationship to any other rock-forming element. But in the basaltic rocks very constantly the weight percentage of F is one-tenth that of P_2O_5, suggesting that apatite in these rocks is the chief carrier of F.

Fluorine in thermal waters of Iceland ranges from zero to 1.45 parts per million. This is about the same as one finds in river waters, but much lower than the figures given by Allen and Day from hot-spring waters of Yellowstone.

Sinter deposits in Iceland contain 0.003 per cent F. Rocks altered by thermal waters are low in fluorine both in Iceland and in the Yellowstone Park. But one rock (from Hverarönd, Iceland) highly altered by fumarole gases has as much as 0.480 per cent F.

Many more analyses are necessary before the geochemical cycle of this freakish element will be understood.

GLACIAL GEOLOGY AT STEEP ROCK LAKE, ONTARIO

M. W. BARTLEY AND R. F. LEGGET

Steep Rock Iron Mines Ltd., Steep Rock Lake, Ontario

Glacial erosion over a period of some 10,000 years is represented by varved clays and silts in the dewatered bed of Steep Rock Lake. These deposits vary in thickness from 15 to 300 feet. There appear to have been five distinct periods of glaciation as represented by the clays and silts. These glacial advances followed directions of S. to S. 20°W. The predominant striae strike S. 15°W.

The area immediately south of Steep Rock Lake is characterized by kame topography and a distinct terminal moraine. This is believed to represent one of the later glacial advances. The debris is essentially till, coarse and unsorted, but locally rude stratification of the sandy layers is noted.

About 4 miles north of Steep Rock Lake a distinct terminal moraine 200 feet high strikes across country E. 12°S. The prolongation of this ridge coincides with known moraines in the Kenora region. The material is essentially unsorted sand containing many boulders but very little clay. This structure is believed to be the final expression of glaciation in the area.

The paper includes a summary of mechanical and physical tests upon typical deposits of the area, principally from the unwatered bed of Steep Rock Lake, which were carried out in connection with engineering studies associated with the development of the Steep Rock Iron Mine.

GROUNDWATER AQUIFERS OF NORTHERN ILLINOIS

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The area treated is that portion of Illinois north of the Pennsylvania boundary. The bedrock includes strata from Cambrian to Devonian in age. Nearly all bedrock formations are productive of ground water at some locality. Ground-water production is also obtained from sands and gravels in the glacial drift. The producing aquifers are generally confined, both in the drift and the bedrock.

There are too types of bedrock reservoirs: (1) the limestones and dolomites which produce from secondary-solution crevices and fractures, and (2) the permeable sandstones. Geological factors controlling productivity include areal pattern of solution crevicing, reef rock-interreef rock distribution in the Niagaran, pre-St. Peter solution and drainage pattern in the lower Ordovician and Trempealeau (Upper Cambrian) dolomites, and the original sedimentation and secondary cementation of the sandstones.

The occurrence of ground water in the glacial drift is mainly in outwash deposits in buried preglacial valleys or in highly permeable zones in the outwash sheets of the deeper drift zones.

The areas of productivity of various aquifers as known to date are outlined. The problems of source of the ground waters and the infiltration-recharge relationships are considered.

ETCHING "CORNEOUS" BRACHIOPODS

W. CHARLES BELL

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Cambrian "inarticulate" ("corneous") brachiopods have attracted little interest from paleontologists since Walcott's papers on their morphology, and in recent years have been almost ignored by stratigraphers. Reasons for such disinterest are not hard to find: shells are small, and their exteriors are often discouragingly alike; interiors are rarely exposed by weathering, and mechanical preparation is a tedious laboratory chore; "the trilobites are better anyway"!

So far as I know, chemical treatment of "inarticulates" has never before been attempted, possibly because the appellation "calcareocorneous shells" implies non-resistance to all acids. However, the writer has successfully freed from a variety of carbonate matrices, by means of acetic acid, perfectly preserved micromitroids, linguloids, and acrotretoids from the Cap Mountain and Wilberns of Texas, Honey Creek of Oklahoma, Bonneterre of Missouri, Dresbach of Minnesota, Deadwood of the Black Hills, Meagher and Pilgrim of Montana, and Wheeler of Utah. The etching program was interrupted in its infancy by military service in 1942, and has only now got underway again.

X-ray analysis shows that the shell-material has an apatite structure. Apparently the degrees of concentration of the acid has little or no effect on the shells; dolomite was etched in hot concentrated acid without visible damage to the enclosed shells of *Curticea*. However, the etched shells range widely in their structural strength, usually are relatively brittle, and should be hardened by some transparent plastic or resin—such as Alvar—before being handled during study or photography.

NEW CONCEPT OF NORTH CAROLINA COASTAL PLAIN

E. WILLARD BERRY

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Recent drilling in eastern North Carolina demonstrates that there is a much greater thickness of sediments than previously recognized. This thicker section would seem to indicate a hitherto unknown peneplain, with a much steeper eastward dip than the older recognized one under the western

part of the coastal plain. This new peneplain surface, for which the name Hatteras peneplain is proposed, is apparently deeply weathered as there is much epidote with the feldspars in the granite. Drill holes have cut this surface at 9990 feet at Hatteras Light No. 1, at 4012 near Moorehead City, and between 4000 and 4100 feet near Merrymans. Earlier drill holes cut the crystallines at from 1900 to 2300 feet.

LIROCONITE

L. G. BERRY AND T. DAVIES

Queen's University, Kingston, Ontario, Canada

X-ray and density measurements on liroconite from Cornwall, England, combined with the existing chemical analyses lead to the following description of this mineral.

Liroconite: monoclinic; prismatic—$C_{2h}^6 - I2/a$; the unit cell, with $a = 12.67$, $b = 7.55$, $c = 9.86$ kX, $\beta = 91°23'$, $a:b:c = 1.679:1:1.306$, contains $Cu_8Al_4(As,P)_4H_{48}O_{48} = 4[Cu_2Al(As,P)O_4(OH)_4 \cdot 4H_2O]$ with As:P in the ratio 3:1. Specific gravity, measured 3.01; calculated 3.08. Des Cloizeaux (1859) obtained monoclinic elements which, transformed to our setting by interchange of a and c, give $a:b:c = 1.6808:1:1.3191$; $\beta = 91°27'$. Observed forms $m(110)$, $e(011)$.

EUCHROITE AND CHALCOPHYLLITE

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New observations on euchroite from Libethen, Hungary, and on chalcophyllite from Braden Mine, Chile, combined with existing chemical analyses yield the following data on these minerals:

Euchroite: orthorhombic; disphenoidal—$D_2^4 - P2_12_12_1$; the unit cell, with $a = 10.05$, $b = 10.50$, $c = 6.11$ kX, $a:b:c = 0.957:1:0.582$, contains $Cu_8AS_4H_{28}O_{32} = 4[Cu_2AsO_4(OH) \cdot 3H_2O]$. Specific gravity, measured 3.41; calculated 3.45. Haidinger (1825) obtained orthorhombic elements which, transformed to our setting by interchange of axes, give $a:b:c = 0.9635:1:0.5866$. Optical characters: biaxial, positive, $Z = b$, optic plane $\parallel$ (001), $2V = 31°$.

Chalcophyllite: hexagonal; scalenohedral, possible space group $D_{3d}^5 - R\bar{3}m$; the unit cell, with $a = 10.75$, $c = 57.40$ kX, $a_{rh} = 20.49$ kX, $\alpha = 30°40'$, $a:c = 1:5.351$, contains $Cu_{18}Al_2As_2S_2H_{34}O_{37} = Cu_{18}Al_2(AsO_4)_3(SO_4)_3(OH)_{27} \cdot 36H_2O$ in the rhombohedral cell. Specific gravity, measured 2.67; calculated 2.60. Palache (1909) obtained elements in hexagonal notation which, with c doubled, give $a:c = 1:5.343$. The museum specimen of chalcophyllite studied here is partially dehydrated with $\omega = 1.68$. After exposure to a moist atmosphere for two weeks ω had changed to 1.62, agreeing closely with the observations of Shannon (1924) on fresh material. The partially dehydrated material has a well-marked pseudo-cell with $a' = a$ and $c' = c/2$.

THREE STAGES OF PLEISTOCENE GLACIATION, BEARTOOTH MOUNTAINS, MONTANA

ARTHUR BEVAN

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Field work during August 1946 on East Boulder Plateau, in the northwestern part of the Beartooth Mountains, Montana, resulted in the tentative identification of three stages of glaciation. The latest stage has long been known—a canyon stage during which huge glaciers occupied the canyons of the Beartooth Range, including the deep Boulder and West Fork of Stillwater canyons adjacent so East Boulder Plateau. An earlier stage, now designated the intermediate stage, was reported in 1945. It is now known that the principal record of this stage consists of a broad lobate

deposit of typical glacial drift at altitudes of 9000 to 9400 feet on the southern part of the plateau. This drift was derived from an interior upland to the south. The earliest known stage of glaciation in this district is indicated by extensive high-level morainic drift far north of the lobate mass and by definitely striated, somewhat weathered roches moutonées on high points (8890 feet) among the igneous rocks of the Stillwater complex near the dissected northern end of the plateau, above the range front which overlooks the near-by plains. Regional correlations under the present lack of definitive data are unscientific. It appears, however, that the three stages of glaciation may be provisionally considered as Early, Middle (?), and Late Pleistocene of the northern Rocky Mountains. (Geological Society project, in part.)

EVOLUTION OF DESERT PLAYAS

ELIOT BLACKWELDER

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The barren clay plains in arid regions, variously called playas, dry lakes, or pans, are the bottoms of former lakes which have dried up but are still subject to flooding at rare intervals. In times of exceptional rain, rills from the bordering slopes generate a shallow lake of muddy water. In this lake a thin layer of sand, silt, and colloidal clay are deposited over the level floor of the basin. At more frequent intervals "cloudbursts" may spread local mudflows around the margin. In the succeeding long dry interval the layer of colloidal mud cracks and curls up. Later the wind blows away all movable material and in so doing classifies it, leaving only scattered boulders where the mudflows once lay, and a polygonal pattern where the deep mudcracks had formed. To leeward of the basin it leaves windrows of lag gravel as well as drifts and low dunes of sand, clay pellets, or salt crystals, depending on the material locally available. In the form of dust the finer deposits are removed from the basin by the wind. Eventually a renewal of the ephemeral lake completes the cycle and starts a new one. In the more arid regions the effects of deflation overbalance those of deposition, and so there is a net loss of material and a progressive lowering of the playa surface. Such playas are areas of erosion rather than of deposition. Only in the merely semiarid regions is the ratio of these processes reversed.

GENESIS OF PEGMATITES IN THE DENVER MOUNTAIN PARKS AREA, COLORADO

MARGARET FULLER BOOS

2036 S. Columbine, Denver, Colorado

Pegmatites from the Falcon granite gneiss, the Mt. Evans quartz monzonite and quartz monzonite gneiss, the Sante Fe Mountain pluton and fringing dikes, the Rosalie lobe of the Pikes Peak batholith, and the Indian Creek plutons (Silver Plume type granite) invaded the Idaho Springs and younger pre-Cambrian formations in the Denver Mountain Parks area in the order named, probably in Algonkian time.

The parent intrusions are peripherally disposed about an area of nearly 75 square miles composed of metasedimentary and meta-igneous beds that have been riddled with thousands of dikes, sills, and irregular bodies of pegmatite.

Field and laboratory studies of the texture, structure, and mineral associations of the pegmatites and their wall rocks indicate that, in many cases, the pegmatites from any one magmatic surge have characteristic features that distinguish them from pegmatites genetically related to the other invasions. Many pegmatites, formed early (Mt. Evans time), are complex and have been repeatedly subjected to replacement and hydrothermal activity, but those injected late (Indian Creek) are chiefly simple intrusions of the "giant granite" type. A few major complex dikes bear the marks of three or more waves of replacing solutions and may have been active from Mt. Evans through Indian Creek time.

GRANITES OF THE FRONT RANGE: PEGMATITES ASSOCIATED WITH THE LONGS PEAK-ST. VRAIN BATHOLITH

MARGARET FULLER BOOS

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Pegmatites are abundant in some areas and very scarce elsewhere in the Longs Peak—St. Vrain batholith and the enclosing metasedimentary formations. At least 90 per cent, by volume, of the pegmatitic material is concentrated in marginal parts of the complex mass of thick granite sheets and cupolaed stocks of the batholith and in contiguous schists. Large bodies of pegmatites show a definite relationship between their size, shape, structure, distribution, and certain environmental conditions in and around the batholith.

The parent magma (Silver Plume type) produced granite with marked trachytoid arrangement of the numerous potash feldspar crystals. Locally this habit extended to the offspring pegmatites. Longs Peak pegmatites carry chiefly potash feldspar, glassy to gray quartz, and muscovite. The satellitic Mt. Olympus granite and pegmatite contain original plagioclase feldspar (albite-oligoclase), smoky quartz, and biotite. None of the many hundred pegmatites examined show replacement minerals or hydrothermal textures. The pegmatites of Longs Peak or Mt. Olympus origin did not develop much beyond the magmatic stage.

SOME GEOLOGICAL CONDITIONS THAT FAVOR ROCK BURSTS

MARGARET FULLER BOOS

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Excavation in rock containing unrelieved stress may produce the violent failure called "rock burst".

Igneous rocks harbor stress due to change in volume when magma freezes. Igneous intrusions induce stress by producing changes in the host rock. Granites, pegmatites, and other massive crystalline rocks have exhibited particularly damaging rock bursts. Recrystallization and replacement of minerals in pegmatites create unrelieved stress within and around the components of the intrusion. Granite under load equivalent to 6500 feet of cover has been known to compress 1 per cent (Sano). The loading of an area by thick beds of lava and pyroclastics will compress the rock below. The rock stressed by compression may rupture severely where free faces are developed during excavation.

Crustal deformations subject rocks to bending, twisting, folding, and faulting. Accommodation of the rock to the new conditions may be incomplete, and unrelieved stress may exist. Dynamometamorphism, particularly where accompanied or followed by igneous activity, may create a new crystal pattern in the rock at depth and engender stress that will cause the fabric to shatter on exposure.

The complex lot of incompletely relieved stresses developed in rock by changing geologic conditions favor bursts during tunneling, stripping, quarrying, or other excavation.

CONTACT DEPOSITS AT UNCONFORMITIES

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Many unconformities have consolidated residual soils above eroded surfaces and below the deposits of an advancing sea. Such deposits have been given little attention in geologic literature, and the question of the classification of a formation composed of the old soils is an open one.

One example described lies on top of the Jefferson City dolomite near the Missouri River in Mi-

souri. Overlying the consolidated soils is a Middle Devonian limestone. The old soils are made up of fragments of practically insoluble residues from the Jefferson City and of small pebbles of chert, chalcedony, and quartz grains from an undetermined source. Several other old soils are described.

The question associated with the soils is their age and to what formation they should be assigned. In most cases they are too thin and discontinuous to make mappable units and they must be mapped with the underlying or overlying formation. In most places where the soils may be studied they are in steep cliffs and whether they are mapped with the overlying or underlying formation is of little consequence. However, their age cannot be determined in most cases. The one mentioned above was formed after the Jefferson City dolomite was consolidated but may have formed after hundreds of feet of Ordovician, Silurian, and Devonian rocks had been eroded away. The age is not that of the immediately overlying formation as seas advanced and removed some of the loose material and left the soils only in protected places. If fossils are present they may have been derived from the underlying formation or from any other formation below Middle Devonian.

The age is a question of little importance, but it may be worth while for geologists to agree to include the soils either with the underlying formation or overlying.

FOOTPRINTS IN THE RED PEAK FORMATION OF WYOMING

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In 1942 Professor Lull described footprints from the Chugwater series near Lysite, Wyoming. Last summer the writer found the locality and collected a few footprints. The formation is the Red Peak of the Chugwater series, about 40 feet below the Alcova; both formations are Lower Triassic in age. Professor Lull said that the footprints were probably from the Permian. Lower Triassic fossils have been described from the Dinwoody which is more than 700 feet below the horizon of the footprints. Lull described three species. The writer found four species, but specimens of the new species are poorly preserved.

FOOTPRINTS FROM THE ABO FORMATION OF NEW MEXICO

E. B. BRANSON AND C. C. BRANSON

University of Missouri, Columbia, Missouri

During 1946 the junior author collected more than 100 slabs containing footprints from red siltstone of the Abo formation. Most of the slabs contain 2 or 3 to 20 prints, but some contain more than 50, and a few only one. The prints range from 10 centimeters to 5 millimeters in width, from 4 centimeters to 6 millimeters in length. Many specimens show prints of all four feet and drag of the tail. No bones or other fossils were found.

Insofar as we are able to determine some of the species may be identical with some described by Gilmore from the Coconino sandstone of the Grand Canyon region. The species have not yet been identified.

STRUCTURE AND OROGENIC HISTORY OF VENEZUELA

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The evidence for a number of conclusions will be given, illustrated with slides based on the manuscript draft of the geologic-tectonic map compiled by the writer for the Venezuelan Government.

1. The Caribbean mountain system consists largely, if not wholly, of the more or less

metamorphosed members of the sedimentary sequence that filled the Cretaceous Caribbean geosyncline (which begins with beds of upper Upper Jurassic age).

2. The first orogenic movement, which produced intrusions and most of the metamorphism, occurred in pre-Senonian or intra-Senonian time. It was, thus, synchronous with the first orogenesis in the island belt of Curaçao, Bonaire, etc., and in the North Caribbean islands, and took place long before the first recognizable deformation in the Venezuelan Andes.

3. In general, the fold axes produced trends oblique to the belt as a whole and symmetrical to the similar oblique trend along the south borders of the North Caribbean islands. This suggests differential horizontal movement of the Caribbean area eastward with reference to its borders. The abundance of northwest-trending normal faults is corollary to the prevailing trend of the fold axes.

4. All later deformation is determined by the development of localized deep trough-shaped basins within the area of the original broad geosyncline.

5. The second major orogenic deformation produced, at some time near the end of Paleogene time, the great belt of imbrication and marginal overthrusts that borders the Western Caribbean Mountains on the south and, swinging northward out to the sea east of the island of Borracha, meets head-on a corresponding belt in the Eastern Caribbean Mountains.

6. The third major orogenic movement, toward the end of Neogene time, produced most of the deformation and the uplift of the Venezuelan Andes.

Critical remarks concerning the stratigraphic timing of the major and minor orogenic movements, with special reference to Stille's nomenclature conclude the paper.

STRUCTURE OF NEPHELINE

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A Weissenberg study of nepheline shows that it belongs to space group $H6_3$ and has cell edges, $a = 10.05$ Å. and $c = 8.38$ Å. The unit cell contains 8 $NaAlSiO_4$.

The intensities of all reflections which can be recorded with filtered copper radiation were determined using a modified Dawton method. From these data Harker syntheses were prepared and studied in the implication diagrams $I3(xy0)$ and $I6(xy\frac{1}{2})$. This permitted location of all the metal atoms, but the oxygen atoms were insufficiently defined to be located by this method.

Assuming that the metal atoms alone determined the hk0 phases, a preliminary electron-density map, $\epsilon\ (xy0)$, was prepared. This roughly revealed the oxygen locations. Employing the new atomic locations, the signs of F(hk0) were recomputed, and a new electron-density map was prepared. By successive approximations the x and y parameters were arrived at.

The z parameters have been studied first by one-dimensional Harker syntheses, $P(x_1y_1z)$, and later by a series of noncentrosymmetrical electron-density projections through planar sections, such as $\epsilon\ (x\ \frac{3}{8}\ z)$ and $\epsilon\ (x0z)$. The parameters arrived at are as follows:

		x	y	z (*approximate*)
$Na_1(=K)$	in 2a	0	0	0
Si_1	in 2b	$\frac{1}{3}$	$\frac{2}{3}$	.82
Al_1	in 2b	$\frac{1}{3}$	$\frac{2}{3}$	.18
O_1	in 2b	$\frac{1}{3}$	$\frac{2}{3}$	0
Na_2	in 6c	.01	.43	0
Si_2	in 6c	.09	.33	.33
Al_2	in 6c	.09	.33	.67
O_2	in 6c	.09	.33	.50
O_3	in 6c	.17	.52	.75
O_4	in 6c	.17	.52	.25
O_5	in 6c	.25	.28	.25
O_6	in 6c	.25	.28	.75

The structure of nepheline proves to be based upon the tridymite structure, with NaAl substituted for half of the Si atoms, as originally predicted by Schiebold. The Na_1 (= K) atoms occupy large holes, and the Na_2 atoms occupy smaller holes produced by collapse of voids in the tridymite structure. Chemical analyses bear out the view that two of the eight alkali atoms are potassium and not sodium, so that the formula of nepheline is ideally $KNa_3Al_4Si_4O_{16}$.

The implication diagram $I6(xy\frac{1}{2})$ provides evidence for assuming that the atoms on the three-fold axes are in motion.

SOME ASPECTS OF THE SPECIES CONCEPT IN THE LIGHT OF QUANTITATIVE PALEONTOLOGY

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Certain differences in the species concept appear when viewed from the standpoint of the newer quantitative paleontology instead of the traditional qualitative paleontology. Two such differences are discussed: (1) It is concluded that there are objective criteria for establishing how many species may be recognized in a given evolutionary line; and (2) it is shown that the criteria usually used to distinguish between species from the same horizon and locality are suspect, and a recent attempt to do so is discussed.

TERTIARY AND QUATERNARY GEOLOGY OF THE TUSAS-TRES PIEDRAS AREA, NEW MEXICO

ARTHUR P. BUTLER, JR.

U. S. Geological Survey, Washington 25, D. C.

The Tusas-Tres Piedras area includes 500 square miles in the Rio Grande depression and in the southeast extension of the San Juan Mountains in north-central New Mexico.

Tertiary rocks resting on a basement of pre-Cambrian rocks include the Conejos and Treasure Mountain formations (Potosi volcanic series), the Los Pinos and Santa Fe formations, and the Hinsdale volcanic series. The first three consist of stream-laid debris, largely of volcanic origin, and pyroclastic and effusive quartz latite, rhyolite, and basalt. The Santa Fe formation is a basin deposit composed largely of sandstone. The Hinsdale volcanic series consists of two basaltic formations and a basin deposit composed of interbedded basaltic lava and gravel, younger than the Santa Fe.

Areal mapping and investigation of the volcanic stratigraphy resulting in redefinition and subdivision of the Los Pinos show (1) no appreciable unconformity between it and the Potosi series, (2) that it is partly older than and partly contemporaneous with the Santa Fe formation (upper Miocene to lower Pliocene), (3) that its material was supplied largely by contemporaneous vulcanism rather than by erosion of older rocks, and (4) that the Hinsdale volcanic series is unconformable on both the Los Pinos and Santa Fe formations. This unconformity probably merges with the San Juan peneplain, which was previously considered older than the Los Pinos formation.

Eastward tilting and displacement on a group of related normal faults deformed the Tertiary rocks, both before and after accumulation of the Hinsdale volcanic series.

MODERN POLYGONBODEN FORMATION IN MAINE*

ARTHUR P. BUTLER, JR. AND LOUIS L. RAY

U. S. Geological Survey

In April 1939, well-developed polygonboden were observed at an elevation of 1025 feet on Cadillac Mountain, Mount Desert Island, Maine. Polygonboden have been previously described in this area at somewhat higher elevations by R. L. and Frances Nichols. They have suggested that these features might be found as low as sea level and are "undoubtedly being formed at the present time."

* Published by permission of the Director, U. S. Geological Survey.

The polygonboden are developed in glacial till in shallow bedrock basins on a glacially smoothed relatively horizontal surface. The polygons in general range from 1 to 2 feet in diameter; the maximum depth to bedrock is about 2 feet. To determine subsurface structure and conditions of the frozen ground, a large area was dug out to bedrock where the material was thickest.

Butler revisited the area in June 1940, at which time no change was noted in the disturbed material. However, in August 1946, when he again revisited the area, an incipient polygonal structure of less perfection than that previously observed had begun to reappear in the disturbed material. The unassorted character of the material, location in shallow bedrock basins, which form a solid base and catchment areas for water, the great number of days in which the temperature crosses the freezing point, the relatively high precipitation, and the lack of vegetative cover provide ideal conditions for the production of this feature of frost action.

CYCLOTHEM SYSTEM OF DETAILED PENNSYLVANIAN CLASSIFICATION AS APPLIED TO PENNSYLVANIAN STRATA IN ILLINOIS

GILBERT H. CADY

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The cyclothem theory during the past 12 years has been extensively applied to the Pennsylvanian beds in Illinois. Results of a study of numerous cores of diamond-drill holes and other studies since 1942 support the validity of the cyclical concept but indicate that the full cyclical sequence has not been listed. The main consideration, however, is whether or not its use has assisted in the solution of stratigraphic and classification problems. Certain proposals concerning the classification and correlation of the McLeansboro group have been advanced as though they marched under the banner of the cyclical theory, but they are actually based upon concepts unrelated or only remotely related to the theory. Even so, because of the manner of their proposal, the fact that the proposals proved in error tends to discredit the cyclical theory, whereas within its restricted field of usefulness this concept seems valid. The usefulness of the concept resides almost solely in the nearly complete invariability of the standard order of deposition and in the effect of this high degree of invariability in emphasizing exceptions. Otherwise it has little or no stratigraphic importance or usefulness in correlation, although exceptions may be stratigraphically significant. Correlation still requires the application of conventional procedure in Pennsylvanian studies, and cyclical sedimentation is not one of the criteria of such procedure.

STRUCTURES IN THE EAST BORDER OF THE COLVILLE BATHOLITH, WASHINGTON

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The east border of the Mesozoic (?) Colville granitic batholith, in east-central Ferry County, has features in common with that part of its border described by Waters 60 miles to the west.

Foliation forms a dome 12 miles wide, elongated northeast parallel to regional fold axes. Along the axis and northwest side of the dome, the foliation is faint and locally highly distorted. Pegmatite is abundant, and the overlying quartzites and mica-sillimanite schists widely granitized. Extensive *lit-par-lit* gneisses, locally forming ptygmatic folds, may be the result of partial replacement of sedimentary rocks, but a sill of gneissic granitic rocks 5000 feet thick, which forms the outer shell of the batholith, is probably truly igneous.

This shell is platy and dips southeast conformably beneath slightly metamorphosed sedimentary rocks. The batholith is mylonitized for several hundred feet from its contact, but, of all the sedimentary types, only the quartzite shows strain shadows and granulation. East-pitching lineation appears as fine grooving in granitic rocks and quartzite, and as an alignment of *c*-axes in quartzite and hornblende schist.

The crushing is believed to be mainly protoclastic, because the shape of the grooving in the granite and of the drag fold near it suggests an eastward and downward slipping of the batholithic roof. The abundant pegmatites to the west may have been injected at this time.

A later reverse movement of a few inches is shown by offset pegmatites and a small broken fold in the foliation of the granite.

CITRONELLE FORMATION OF SOUTHWEST ALABAMA

CHARLES W. CARLSTON

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The Citronelle formation in southwest Alabama is 40 to 129 feet thick and generally consists of a thin basal gravel overlain by a lenticular irregularly bedded sequence of sand, gravel, and multicolored clay. The distribution of the formation and the lithology of its gravel indicate deposition largely by the Alabama River with some sediment contributed by the Tombigbee River.

There is some evidence of marine benches cut in the Miocene Catahoula sandstone and buried by the continental Citronelle. Only one marine terrace, the 20-foot "Pensacola" terrace, is present on the Alabama Coast. No evidence of cyclical stream terraces cut in the Citronelle and underlying Catahoula sandstone could be found along the streams of southwest Alabama.

Although no fossils have yet been found in the Citronelle, the discovery by G. F. Brown of Pliocene and Pleistocene fossils in the pre-Citronelle Graham Ferry formation in Mississippi accords with geomorphic evidence which suggests a middle to late Pleistocene date of deposition.

DEVELOPMENT AND RELATIONS OF THE PARASPHENOID BONE

E. C. CASE

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This paper presents for discussion certain points in the development and relations of the parasphenoid bone in the fossil vertebrates.

GREAT TRENTON "DELTA" IN NEW YORK

GEORGE HALCOTT CHADWICK

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Sedimentation in New York during and after Trenton time, as well as farther east in pre-Trenton time (rocks subsequently overthrust into eastern New York), followed closely the facies and thickness pattern of Middle and Upper Devonian strata later deposited in approximately the same area. There will be exhibited a carefully plotted cross section of the beds according to their actual thicknesses from Lake Ontario to Albany, showing some novel correlations based upon the principles found to control in the Devonian strata: the "Frankfort" turns out to be a facies that diagonals eastward down across the Utica (Cobourg) and eventually the Trenton; the Indian Ladder beds are an eastern outlier of facies of the lower Utica owing their preservation to downfaulting before pre-Silurian erosion. In the chart, ironing out the faults in the Ordovician gives the Silurian the false appearance of being contrarily faulted on top of them. The facies pattern is (a) limestones ("Trenton") at west (showing no thickening eastward while they remain pure), enlarging into (b) black shale ("Utica"), then (c) sandy-shaly beds ("Frankfort"), and finally (d) redbeds (for example, Queenston) at extreme east now mostly lost by erosion above the Normanskill.

THE CRUX OF GEOLOGY

GEORGE HALCOTT CHADWICK

Catskill, New York

To the geologist has come the unique opportunity of deciphering the sequence of past life and the history and causes of decadence of each successive dominant race. On the geologist, therefore, rests the responsibility of guiding the human race, now dominant, into such understanding of the laws of evolution and survival, and of the premonitory symptoms of extinction, that our race, the first to have the intellect to investigate and act upon such knowledge, may be the first to turn the same to its own permanent prolongment upon earth. Present trends (such as survival of the unfit under "civilization," self-destruction in wars that claim the best fit, softness of living, too close adaptation to a single environment that is in danger of change, and other equally evident symptoms) warn that our responsibility can no longer be lightly neglected.

VANISHING ADIRONDACKIA

GEORGE HALCOTT CHADWICK

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The paleogeographer's conception of the Adirondack area as an island area supplying land wash through much of Paleozoic time appears unsupported by the sedimentary strata surrounding the present dome of uplift. After Glens Falls time the facies pattern in the Ordovician, and again in the Middle-Upper Devonian, deposits shows sources only to the east and south of New York State, no trace of any land to the north. For most of Cambrian and early Ordovician time the Adirondack region was only a northward promontory from much larger lands lying south of the Mohawk of today. In Silurian time, the uplift was in the Taconic region, and the great Taconic overthrust itself found no impediment to its movement in the Adirondacks. In early Devonian time the uplifted region was that of western New York, and even the Oriskany sand reaches its maximum expression far south in central Pennsylvania—not toward the Adirondacks. What clinching proof is there that "Adirondackia" supplied any Paleozoic sediment after Potsdam time?

STAUROLITIC ZONES ALONG QUARTZ VEINS IN SCHIST

CARLETON A. CHAPMAN

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Quartz veins up to a foot wide cut staurolite schist of the Littleton formation (Lower Devonian) in west-central New Hampshire. The schist is medium-grained and composed of quartz, muscovite, and biotite with numerous porphyroblasts of staurolite. The staurolite is in crystals averaging 1–2 inches long and is locally much more abundant in certain beds of the formation.

Along the vein walls in the schist are zones (1–2 inches wide) showing a marked concentration of staurolite crystals which appear, in all respects, like the porphyroblasts more uniformly dispersed throughout the rock. In places these zones are composed almost entirely of staurolite. Large crystals of staurolite also occur locally in the quartz veins.

It is concluded that the quartz veins have influenced the localization of staurolite in the wall rock by transporting and supplying large quantities of certain components (principally Al_2O_3) essential to the formation of this mineral. The migration of this material along the veins may have involved distances exceeding many tens of feet, because the contact zones appear as well developed where quartz veins cut beds otherwise poor in staurolite as where the veins cut beds rich in staurolite.

CRYSTALLIZATION PHENOMENA IN VOLCANIC EJECTA FROM KILAUEA, HAWAII

RANDOLPH W. CHAPMAN

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The eruption of Kilauea volcano in Hawaii in May 1924 was of particular interest because it involved many violent explosions, phenomena not common to Kilauean activity. During the eruption a large number of angular blocks of lava were expelled from the volcano's orifice and scattered over the floor of the caldera around the great firepit, Halemaumau.

One particular rock type is a glass-bearing basalt consisting of microphenocrysts of olivine and augite set in a groundmass of labradorite, augite, and basaltic glass, with minor accessories. The labradorite and most of the augite are arranged radially, forming variolitic structures about 3 millimeters in diameter. Glass fills the interstices between mineral grains.

The texture of the basalt and the paragenesis of its minerals suggest that the normal basaltic magma, from which it was apparently derived, passed through three distinct stages in the process of cooling. During Stage 1 the magma cooled slowly and developed microphenocrysts of olivine and augite. Stage 2 began when the magma was intruded as a sill-like mass into the hot walls of the Halemaumau firepit. The magma, now cooling more rapidly, precipitated crystals of labradorite and augite as radial intergrowths. In Stage 3 portions of the intrusion were torn violently from the wall of Halemaumau firepit and hurled high into the air, causing the residual liquid in the pore spaces to be chilled to a glass.

PETROLOGY AND STRUCTURE OF THE PERCY QUADRANGLE, NEW HAMPSHIRE

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The Percy quadrangle, located in northern New Hampshire, is bounded on the north and south by latitudes 44° 45′ and 44° 30′ and on the east and west by longitudes 71° 15′ and 71° 30′ respectively. It embraces an area of rugged topography which has been maturely developed by stream action and subsequently modified by continental glaciation. The region is drained chiefly by the Upper Ammonoosuc River which flows generally westward into the Connecticut River.

Strongly folded and metamorphosed micaceous quartzites and schists of the Albee formation and somewhat younger amphibolites of the Ammonoosuc volcanics constitute the oldest (upper Ordovician ?) rocks of the region. These are intruded by rocks representing four distinct magma series: (1) Lost Nation quartz diorite (Highlandcroft magma series, upper Ordovician ?); (2) quartz diorite, biotite-quartz monzonite, and coarse syenite (Oliverian magma series, middle Devonian ?); (3) Long Mountain two-mica granite (New Hampshire magma series, upper Devonian ?); and (4) syenite and granite (White Mountain magma series, Mississippian ?).

Ring dikes and stocks, composed of syenite and granite of the White Mountain magma series, form features of particular interest in this quadrangle. Most of these structures are believed to have been emplaced by ring-fracture stoping or cauldron subsidence. In some cases the process appears to have involved wholesale intrusion of magma into clean-cut arcuate fractures; in other instances arcuate shatter zones apparently developed, and these were intruded by multitudinous small dikes which gradually replaced the country rock.

DIFFERENTIAL THERMAL ANALYSIS OF SOME CARBONATE MINERALS

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Baroid Sales Division, National Lead Company, Los Angeles, California; Shell Oil Co., Houston, Texas

Differential thermal-analysis curves are presented for 10 of the more common carbonate minerals of known purity. The characteristic curves given should aid in detecting the presence of these minerals when they occur in clays or soils being analyzed by this method. The use of differential thermal analysis is suggested for industries utilizing carbonate minerals or their by-products.

GEOLOGY OF MARSHALL FORD DAM

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Marshall Ford Dam is situated on the Colorado River of Texas in the western part of Travis County about 13 miles northwest of Austin. The dam was designed by and built under the direction of the Bureau of Reclamation and was turned over recently to the Lower Colorado River Authority, a State board, for operation.

The foundations and abutments of the dam are composed of alternating beds of hard and soft limestone, sandy lime, marl, and shale. These strata belong to the lower section of the Glen Rose formation, a part of the Comanche series of Cretaceous age. The Glen Rose formation is essentially marine in origin and represents deposition in shallow or moderately deep water.

Pre-construction investigations, carried on principally by use of diamond drills and a 36-inch diameter calyx drill, revealed that the foundation conditions were satisfactory and the rock competent to support the proposed structure. With the exception of a few well-defined porous zones the rock was impervious. These porous zones were successfully sealed by grouting, tunneling, and back-filling with concrete.

Excavation during construction proved that the dam axis chosen on the basis of the preliminary borings was well located; a few minor fractures were revealed, but otherwise conditions were as anticipated. The dam has been in service for over 25 years.

ADDITIONAL CAMBRIAN GRAPTOLITES FROM TENNESSEE

CHARLES E. DECKER

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An excellent additional collection of Cambrian graptolites were secured in June 1946 from the Tecoy quarry northwest of Knoxville, Tennessee. The collection contains a large number of slabs on which are preserved many beautiful complete dendroid colonies. Slides showing these new forms will be presented, and their characteristics and correlative value will be discussed.

DOLOMITE DEPOSIT NEAR MARBLE, WASHINGTON

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Dolomite constitutes an isolated hill 2 miles east of Marble, Stevens County, Washington. The hill trends N. 55°E., is surrounded by glacial lake sands, silts, and gravels, and more than a fourth of it is covered with glacial drift. The dolomite is part of the Northport limestone (Cambrian) and is overlain by the Mission argillite.

The dolomite is part of the southeast limb of the Northport anticlinorium, is much jointed, and is broken by six or more dip-slip (?) normal faults that form two sets. The older set strikes N. 55°-60°E. and dips 66°–78°NW. The younger set strikes N. 10°–23°E., dips 72°–80°W., and offsets the older. Nine lamprophyric dikes, 4 to 25 feet in width and 20 to 180 feet in length, were intruded along faults or joints parallel with them. The dikes constitute only a small part of the hill.

The rock is light-gray but locally banded black-gray, finely crystalline, obscurely bedded dolomite that contains much glassy quartz irregularly distributed in veins, nodules, vuggy masses, and breccia cement. The silica probably was deposited by hydrothermal solutions derived from Middle or Late Tertiary silicic magmas. Assays and an estimate of observable quartz in the outcrops suggest that the dolomite deposit contains an average of more than 2½ per cent impurities. As evidence was not seen that the dolomite was formed by hydrothermal replacement, the rock may be sedimentary or diagenetic in origin.

SEISMIC-REFRACTION SURVEY OF BIKINI ATOLL*

M. B. DOBRIN, B. L. SNAVELY, G. WHITE, R. BERESFORD, B. PERKINS, JR.

In connection with the atomic bomb tests of 1946 the Bureau of Ordnance Instrumentation Section and the Oceanographic Section under Joint Task Force One conducted a reconnaissance seismic-refraction survey of Bikini Atoll to determine the subsurface structure. Depth charges were exploded on the bottom along four profiles across the lagoon. The resulting seismic waves were received by hydrophones on the bottom at the ends of the profiles. Distances from shot to hydrophone were determined from the travel time of the sound wave through water.

The time-distance plots indicate two sharp interfaces between three distinct zones having respective wave velocities of 7000, 11,000 and 17,000 ft./sec. The first zone is approximately 2000 feet thick and most likely is composed of calcareous sediments similar to those being deposited at present. The second zone varies in thickness from 3500 to 11,000 feet and may be pyroclastic material or a limestone of different type from the first zone. The third zone (thickness undetermined) is probably the igneous basement.

The geophysical evidence appears to support the point of view that considerable relative subsidence has occurred during the formation of at least some coral atolls.

PALEOZOIC CORDILLERAN GEOSYNCLINE AND RELATED OROGENY

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The Cordilleran geosyncline in Paleozoic time consisted of two main troughs, a western, the Pacific, and an eastern, the Rocky Mountain. The sediments of the western trough from California to Alaska are characterized by a large amount of volcanic material and graywacke in every system. Phyllites, slates, argillites, schists, gneisses, recrystallized chert, marble, metaconglomerate, metaandesite, and various metamorphosed pyroclastics make up the thick sequences. Great batholiths of Mesozoic age invaded the sediments of the Pacific trough, and only in one place, the Idaho batholith, did they reach the Rocky Mountain trough.

Dynamic metamorphism and the great intrusives together with blanketing Cenozoic deposits have left the medial area between troughs little known. The Rocky Mountain trough contains mostly marine limestones, shales, and sandstones. Many of the sands are cemented with silica and termed quartzite, but little metamorphism has occurred, and none has been assigned to Paleozoic orogeny.

The volcanic materials are nearly all andesites and came from the west. Since the sites of extensive accumulation of andesitic flows and debris today are in troughs adjacent to island archipelagos, it is suggested that a volcanic archipelago flanked the Pacific trough on the west. The Paleozoic graywackes and conglomerates also came from the west and from Paleozoic rocks already metamorphosed before erosion. Several angular unconformities indicate orogeny in the belt to the west. The island archipelago was therefore a site of continuing orogeny during the Paleozoic. It was very similar to the island arcs of the present Japanese archipelago.

Instead of a rigid land of continental proportions with a shore in western Montana, a volcanic orogenic archipelago is believed to have existed which for the most part lay west of our modern coast.

SIGNIFICANT EXPOSURE OF FOUR TAZEWELL TILLS

GEORGE E. EKBLAW

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Four tills deposited by as many separate advances of the continental glacier during the Tazewell substage of the Wisconsin stage are exposed along the sides of the excavated spillway for the Bloom-

*Work reported here was done under the auspices of Joint Task Force ONE by the Naval Ordnance Laboratory Low Frequency Group of the BuOrd Instrumentation Section and by the Seismology Group of the Oceanographic Section.

ington-Normal, Illinois, municipal water-supply reservoir along Money Creek. These tills from oldest to youngest are identified as Shelbyville, Leroy, Bloomington, and Normal and are separated respectively by a striated boulder pavement with slight weathering, a bed of fossiliferous silt and peat, and a bed of greenish or reddish lacustrinelike clay. These deposits establish that appreciable intervals of time elapsed between the successive retreats and readvances during the substage, and this is corroborated by less striking evidence at other localities in the region.

OUTLINE OF PROGRESS IN METHODS OF SCIENTIFIC AND ECONOMIC PALEONTOLOGY

MAXIM K. ELIAS

University of Nebraska, Lincoln, Nebraska

Usefulness of fossils in pure and applied paleontology depends to considerable extent on philosophical outlook of a paleontologist, methods of collecting and preparation, and personal experience.

In the last few decades the problems of paleontological research and service became considerably augmented by demand for greater precision, scientifically and economically—that is, in its application to stratigraphic geology. Greater precision in differentiation between closely related fossil organisms is particularly important for their advanced use in differentiation of successive stratigraphic units whose lithology is similar. Usefulness of fossils under these and similar circumstances is directly proportional to progress in understanding what these fossils mean as organisms and as indicators of environment, what their evolution was, and how they migrated to or from their place of burial in the course of geological time. In other words, a better biologic understanding of fossils and of their apparent evolution is essential for a progress in their use for economic geology. In turn, progress in their economic use enriches science through accumulation of a more complete and precise record of ancient life and its evolution. Geneticists, and students of organic evolution in general, are, or should be, greatly interested in evolution of fossil organisms as it actually occurred, which is not necessarily as theoretically postulated or expected by them, through comparative study of living organisms, or by observations of some changes in them noticeable within the span of human life.

PROGRESS IN INVESTIGATION OF COILED FENESTELLIDS

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Among the silicified Bryozoa liberated from the Permian limestones of Glass Mountains by dissolution of the matrix, a few coiled forms were discovered. Though coiled tightly like most species of *Archimedes*, they lack, however, the screwlike shaft, so typical of the latter. In its place there is a hole, as in a spiral stairway, and there is only a slight thickening of phytomorphic encrustation and also development of a few pillars along the edges of the axial hole of helicoid.

Summarizing the known cases of fenestellids with coiled zoaria, three principal types can be recognized: (1) Coiling without development of an encrusted screwlike central shaft. Examples: new species of *Fenestella* from the Permian of western Texas; and probably Claypole's *Helicopora latispiralis* (1883) from the Upper Silurian at Cedarvale, Green County, Ohio. (2) Lax coiling with considerable concentration of encrustation near geometric axis of helicoid, resulting in a cork-screw structure. Examples: *Archimedes nikiforovae* Condra and Elias from the basal Artinskian of Russia; *A. utahensis* Condra and Elias and *A. oquirrhensis* Condra and Elias from the Oquirrh formation (Des Moines) at Stockton, Utah; *A. laxus* Hall from the Chester of Illinois; and *Archimedes* (*Helicopora*) *ulrichi* (Claypole) from the lower Helderberg (lower Devonian) from near Louisville, Kentucky. (3) Moderate to tight coiling, with considerable central encrustation, resulting in development of straight to cork-screw central shaft. Examples: most of the species referred to genus *Archimedes*, ranging in age from the Keokuk (upper Mississippian) of Iowa and Illinois, to Artinskian of Russia.

Transitional forms exist between these three types of helicoidal zoaria of fenestellids.

Small and slender forms of *Archimedes* were recently discovered among the fossiliferous rocks

collected by Dr. C. W. Tomlinson from the Springer formation (basal Pennsylvanian) near Ardmore, Oklahoma.

SUBMARINE GEOLOGY OF BIKINI ATOLL*

K. O. EMERY

U. S. Geological Survey, Washington, D. C.

The program for investigating the effect of the atomic bomb tests last summer at Bikini Atoll provided a rare opportunity for obtaining information on the physiography and sediments of atolls. The outer slopes around Bikini Atoll rise from a depth of about 2500 fathoms in a long curved sweep which becomes steepest near the surface. Between 0 and 200 fathoms the average slope is 25°. On the windward side, the reef at the top of the slope is bordered by a narrow 15-fathom terrace, but on the leeward side by a steep, locally vertical cliff extending to 35 fathoms. Contours of the outer slopes reveal that a flat-topped mass having nearly the area of Bikini lagoon but below 700 fathoms extends to the northwest. The lagoon itself is saucer-shaped and has a maximum depth of 34 fathoms. Around the lagoon and bordering the inner side of the reef and islands is a 12-fathom terrace. Coral patches (coral heads) rise abruptly from the lagoon floor, and some of them reach to within a few fathoms of the surface. They are most abundant in the eastern half of the lagoon particularly near the edge of the lagoon terrace. The middle of the lagoon is floored chiefly by algal debris, whereas the shallow edges are covered by algal and foraminiferal sand. Coral comprises a relatively small percentage of the bottom materials. The outer slopes consist of algal debris grading outward to fine sand and finally to *Globigerina* sand.

DEVELOPMENT OF METAMORPHIC ROCK STRUCTURES AND FABRICS NEAR GOUVERNEUR, NEW YORK

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Metamorphic structures and fabrics in the pre-Cambrian Grenville series and in intrusives near Gouverneur, New York, apparently imply two approximately perpendicular directions of movement.

The area studied includes parts of one or more major anticlinal folds that lie on the southeast flank, and form major components, of an anticlinorium. The axes of the component folds and of the anticlinorium strike northeast, imparting a regional trend to the pre-Cambrian rocks. Cross folds, which lie athwart the regional trend, plunge north to northwest on the noses and down the flanks of the component isoclinal folds.

The oldest foliation observed tends to follow relict bedding in the metasedimentary rocks. The development of cross folds in the bedding-foliation was accompanied by shearing and rotational movements, which superimposed foliation surfaces, shear ruptures, and lineations on the earlier structural features. Lineations are both parallel and normal to the axes of the cross folds. The lineations are due to subparallelism of (1) intersections of foliations and shear surfaces, (2) elongate minerals and elongate aggregates of minerals, (3) elongate rock fragments, and (4) slickensides and grooves on shear surfaces.

The northeast-southwest trend of major folds resulted from pronounced movement along northwest-southeast lines. But the north- and northwest-plunging cross folds, associated foliation, shear surfaces, and lineations are related to pronounced movements in a northeast-southwest direction, essentially along or at low angles to the regional trend lines.

These evidences of two directions of movement do not necessarily imply two periods of deformation. All the features may have originated by major shortening, due to compression and couple, along northwest-southeast lines, accompanied by lateral elongation and cross folding in a northeast-southwest direction.

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GEOPHYSICAL INVESTIGATIONS IN THE EMERGED AND SUBMERGED ATLANTIC COASTAL PLAIN, PART V. CAPE MAY, NEW YORK, AND WOODS HOLE SECTIONS

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Seismic refraction measurements from the coast line to the edge of the continental shelf were made along three lines of traverse: near Cape May, N. J., New York, N. Y., and Woods Hole, Mass., respectively. An unconsolidated layer with velocity about 5800 ft/sec, a semiconsolidated layer with velocity about 11,500 ft/sec, and the basement with velocity about 18,000 ft/sec were traced across each traverse. Reversed profiles were used to determine slopes and true velocities. A fourth traverse, started at Cape Porpoise, Maine, and carried only about 30 miles off shore, showed negligible cover over the basement.

On the Cape May traverse, the thickness of the sedimentary column runs from about a mile near the beach to about 3 miles near the edge of the shelf, in general agreement with the findings on the Cape Henry traverse in 1935. The well on Cape Hatteras, which recently reached basement at 9878 feet, confirms the seismic results. The cross-section area of the sedimentary prism off Woods Hole is much less than that off New York, which in turn is less than that off Cape May. Depth to basement increase abruptly near the beach at Cape May, and about 40 miles off shore at New York. The basement starts to slope upward at or just beyond the edge of the continental shelf.

SEARLESITE FROM THE GREEN RIVER FORMATION OF WYOMING*

JOSEPH J. FAHEY

Geological Survey, Dept. of Interior, Washington, D. C.

Searlesite has been found in the drill core of the John Hay, Jr. Well No. 1 at a depth of 1480 feet and in the Union Pacific drill core No. 4 at 1706 feet, approximately 18 and 20 miles respectively west of the city of Green River. This is the third recorded occurrence of searlesite.

Searlesite occurs in low-grade oil shale associated with shortite and an undetermined fibrous mineral. Large anhedral crystals 5 cm. across and up to 3 mm. thick lie parallel to the bedding of the shale.

The optical properties of the searlesite from Wyoming agree with those already determined. The indices of refraction were measured in sodium light: $\alpha = 1.525$, $\beta = 1.531$, and $\gamma = 1.535$. X-ray diffraction photographs and chemical analysis identify the Wyoming mineral as searlesite.

SIX-TARGET COLD-CATHODE X-RAY DIFFRACTION UNIT

H. W. FAIRBAIRN

Mass. Inst. Technology, Cambridge, Mass.

Using basic designs described by Buerger and Chesley a cold-cathode diffraction unit has been built which, by rotation of a taper sleeve in the side of the tube, gives Cu, Fe, Co, Ni, Cr, or Mo radiation as desired, without disturbance of the operating gas pressure. This feature increases many times the efficiency of work where more than one target is essential, such as (1) identification by the powder method of crystalline compounds of wide compositional range, (2) precision determination of lattice constants by the single-crystal method. Additional features of this improved equipment are (1) elimination of autotransformers and rectification valves, (2) use of a transformer instead of a resistor to control the primary current, (3) permanent seals for the windows (beryllium) and for the glass insulating cylinder, (4) adjustable target-cathode distance, and air-cooling of cathode without a blower, (5) unusually short evacuation line direct to a mechanical pump, with the air intake valve mounted directly on the tube, (6) short target-collimeter distance and rigid attachment of camera base to frame of tube.

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THERMAL ANALYSIS OF THE MAGNESIUM MINERALS OF THE CURRANT CREEK MAGNESITE DEPOSITS, CURRANT CREEK, NEVADA*

GEORGE T. FAUST

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Thermal-analysis methods were used in connection with the study of the mineralogy and petrology of the Currant Creek magnesite deposits of Nevada. The minerals present are carbonates, hydroxides, and basic carbonates of the hydrous magnesium silicates. Some relationships with other occurrences of related minerals are outlined.

UNIT CELL OF GLAUCODOT

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A large typical crystal of glaucodot (Co, Fe)AsS, from Hakansbö, Sweden, shows a good prismatic cleavage (110) and a poor pinacoidal cleavage (001), in the preferred original setting. Rotation and Weissenberg photographs on a cleavage fragment turned about [001] show no significant departure from orthorhombic symmetry and lead to a C-type cell with $a = 6.63$, $b = 28.33$, $c = 5.63$ kX, $Z = 24$, $G = 6.15$ (calc. for Co:Fe = 1:1), 6.06 ± 0.05 (meas. Frondel). Additional abnormal systematically missing spectra indicate, however, that this is an apparent lattice due to two coexisting rectangular lattices: I, P-type, with $a' = a/2$, $b' = b/2$, $c' = c$, $Z' = 6$; II, C-type, with $a'' = a$, $b'' = b/3$, $c'' = c$, $Z'' = 8$. The lattice II, which is the weaker, compares with that of arsenopyrite ($a = 6.42$, $b = 9.51$, $c = 5.65$ Å, Buerger) and is clearly reflected in the morphology. The only existing cell dimensions for glaucodot are $a = 6.67$, $b = 4.81$, $c = 5.73$ Å (de Jong, powder method).

THREE-DIMENSIONAL PROJECTION IN GEOLOGICAL TRAINING

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In November 1940 the writer built a twin projector using 500-watt bulbs; each objective carried a polaroid plate. This was fitted to take 2 by 4 3/4-inch glass slides in which were mounted a stereoscopic pair of photographs made on standard (double frame) 35 mm. film, either black and white or colored. Later a simple stereoviewer with which students could individually study the stereoslides was described. Brief directions for taking stereophotographs with a single lens camera and for mounting stereopairs in slides to be used for projection purposes were included.

The writer now has nearly 500 stereoslides, many in color. A small selection from these will be shown. Besides illustrating various subjects by means of vertical aerial photographs, some of which are accompanied by matching contour maps or terrestrial stereophotos, slides will be shown of applications of morphological, optical, physical, and structural crystallography. This occasion will also be taken to demonstrate a simple (nonstereoscopic) projection of the famous Mitscherlich experiment on a modified piece of standard apparatus; this presents in color the decrease of optic axial angle (to uniaxiality) in gypsum with rise in temperature.

There is need for co-operation in preparing stereoslides for use in the various phases of geological instruction. Block diagrams and structural interpretations are obvious fields. There should be many possibilities for phantom stereopairs, such as would show an indicatrix properly placed inside a crystal drawing. These may also be made by photography—for instance, the photograph of an armature and then the motor casing to fit around it (double exposure stereophotography). The writer would like to hear from those interested in stereoscopic work as applied to geological sciences and would be glad to exchange copies of suitable stereophotographs.

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GEOLOGY OF THE NORTHERN GROS VENTRE MOUNTAINS AND MOUNT LEIDY HIGHLANDS, TETON COUNTY, WYOMING

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The northern Gros Ventre and Mount Leidy Highlands area is located in western Wyoming, south of Yellowstone National Park and on the eastern side of Jackson Hole. The rocks of the area range from pre-Cambrian to Tertiary in age. One new formation, which overlies the Cretaceous Mesaverde formation, is described. It consists of approximately 175 feet of sandstone, shale, and coal.

Most of the structures in the area were formed during three phases of the Laramide orogeny: an early period of folding in latest Cretaceous time, a period of thrusting and folding in Middle Eocene, and a final period of faulting in late Middle or Late Eocene. Large parallel, asymmetrical folds which make up the Gros Ventre Range were formed in the first period of folding. Gentle folds which are present in the Mount Leidy Highlands were formed in the second stage of deformation. In Miocene time great rift faults which cut across the Laramide structures were formed. The Camp Davis formation accumulated in one of the downfaulted basins which came into existence at this time.

In Pliocene and Pleistocene time stream erosion of the highlands resulted in the formation of the surfaces and terraces of the Fremont, Union Pass, Black Rock, Circle, and Lenore cycles of erosion. Glacial deposits show three stages of glaciation: the Buffalo, the Bull Lake, and the Pinedale. Although Jackson Hole probably came into existence as a fault trough, much of its present character is the result of glacial erosion.

BURIED PLEISTOCENE GORGE OF MARIAS RIVER, MONTANA

PORTLAND P. FOX

Bureau of Reclamation, Billings, Montana

The bedrock profile of the buried preglacial channel of the Marias River in Liberty County, Montana, has been determined by a number of diamond drill holes recently completed under the direction of the Bureau of Reclamation in connection with investigations of a proposed damsite. The area concerned is in the Great Plains approximately 125 miles east of the Northern Rocky Mountains in Ts. 29 and 30 N., and R.5 E.

The bedrock profile, normal to the filled valley, is a central gorge more than 250 feet deep and half a mile wide at elevation 2900. The buried gorge is south of the present river channel and is flanked on both sides by a buried bedrock terrace 1½ miles wide between elevations 2900 and 2950. The rock terraces are covered by 75–100 feet of yellowish-gray glacial till. One drill hole near the center of the gorge, in T. 29 N., R. 5 E., Sec. 6, penetrated 310.6 feet (to elevation 2652.7) of gray and buff till, fine sand, and pebbles without reaching bedrock.

The preglacial valley was cut in flat-lying Cretaceous shales and sandstones to a minimum depth of about 650 feet below the upland summits (about elevation 3300) of these sediments.

Since the Mankato (Lake Wisconsin) ice sheet did not extend into this part of Montana, the valley filling must be as old as the Iowan stage of the early Wisconsin.

TOURMALINE PRESSURE GAUGES

CLIFFORD FRONDEL

Harvard University, Cambridge, Mass.

During the war years, single crystals of tourmaline were an important industrial raw material for use in piezoelectric gauges for the measurement of blast pressures in air and under water. The gauges comprise thin discs of tourmaline from ¼ inch up to several inches in diameter cut perpendicular

to the *c*-axis and used singly or in stacks. The design and construction of the gauges are described in detail. The piezoelectric response of the tourmaline to the transient pressure wave is amplified and recorded on associated electronic equipment, and both the magnitude of the pressure and the wave-form deduced thereby. Transient gauge-pressures of less than an ounce to over 40 tons per square inch have been investigated by such means.

The sources of supply, price, and factors determining the usability of raw tourmaline for the purpose are discussed. Tourmaline for radio oscillator plates must be entirely free from imperfections and requires crystals of gem quality, but material for gauges can contain a considerable amount of cracking. Most of the tourmaline employed was of low-iron, high-alkali types from Brazil and Madagascar, and the domestic production was negligible. Black tourmaline is generally unsuitable. Crystals over 2 inches or so in cross section were in particularly short supply. Such crystals are used in the construction of air-blast gauges, in which the relatively low incident pressure, at most only a few hundred psi, must be compensated by increased surface area of the discs in order to obtain an adequate signal. Tourmaline is responsive piezoelectrically to hydrostatic pressure and because of this and its high mechanical strength and chemical stability is used in preference to quartz and various water-soluble salts such as ADP and Rochelle-salt.

GEOLOGY AND STRUCTURE OF TALC DEPOSITS AND ASSOCIATED ROCKS OF MURRAY COUNTY, GEORGIA

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Thrust faults supplementary to the mapped overthrust, which separates the eastern crystalline block from known Paleozoic sediments of the Great Valley, bring up a pre-Cambrian biotite augen gneiss (Fort Mountain gneiss) intruded by granite, upon which Ocoee rocks are unconformable in Murray County, Georgia. These Ocoee sediments, composed of fragments of the underlying gneiss and granite, are essentially unmetamorphosed, thus are of assumed Lower Cambrian age.

Talc deposits and associated schists (Cohutta schist) occur in the upthrust block of Fort Mountain gneiss but not in the Ocoee series. They are very dolomitic and, although previously described as of igneous origin, contain no relict igneous structure. They are believed to represent metasediments included in the metaigneous Fort Mountain gneiss. Cohutta schist includes quartz-biotite-chlorite schist, chloritic slate, serpentine schist, and talc deposits (talc, chlorite, dolomite, and serpentine).

Many inclusions of Cohutta schist, with or without talc, occur in the gneiss. Nearly 50 per cent of potential talc-producing rock is covered by fans; thus mines are confined to valleys.

Structure within the talc-bearing zones is dominated by thrust faults and minor normal faults. Stresses were released within these zones because of the lubricating characteristics of talc. Serpentine-dolomite boulders of all sizes, slickensided and enwrapped by schistose talc, determine mine plans. Crayon talc and white and dark grinding talc are produced.

This talc industry, active since 1900, has processed more than 300,000 tons of talc. Reserves in active mines are large; the district has talc reserves amounting to millions of tons.

APPLIED ENGINEERING GEOLOGY AT SHASTA DAM, SACRAMENTO RIVER, CALIFORNIA

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Shasta Dam, a curved, gravity dam 602 feet high, is founded upon a formation designated Copley meta-andesite by Diller. At the dam it consists dominantly of metatuffs, agglomerates, and conglomerates and lesser amounts of amygdaloidal meta-andesites and basalts all cut by a dacite porphyry dike, a hornblende augite diorite dike, and innumerable hornblende-rich lamprophyres. All the rocks are minutely shattered by severe fracturing and small-scale faulting.

Detailed geological studies for preconstruction design data continued during construction to aid

in thorough foundation treatment. Controlling geological features were faults and shear zones in which greater deformation under load could occur than in sound rock and where excessive uncontrolled seepage could cause severe uplift pressures. A foundation map, scale 1 inch = 20 feet, showed all faults, seams, and prominent joints, size of the seam, attitude, amount of gouge, staining or "mud" on joints, and vein filling. Lithology was mapped but was not a major factor in engineering problems.

Trenching on less competent zones minimizes unequal deformation. Trench depths were based on the physical condition of the rocks, zone width, and dam height (load). Bearing tests at loads up to 100 tons per square foot determined relative competency and permitted calculation of moduli of elasticity for rocks of varying physical condition in place and at various orientations with respect to geologic structures.

Special treatment to prevent excessive seepage on selected seams consisted of blocking them with deep shafts and special grout holes to intersect the seams at various depths.

MINERALS OF STEAMBOAT SPRINGS, NEVADA

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Recent studies at Steamboat Springs have brought to light many features of interest to geologists. Many minerals have been found that have not been previously reported from the area. Deposition of stibnite and gold at the surface is of frequent occurrence, and mercury has been detected in the gases. Cinnabar, notwithstanding published statements to the contrary, is abundant in the siliceous sinter. Sulfides, deposited in granodiorite, have been oxidized with the formation of sulfuric acid and numerous sulfates of copper and iron. The descending sulfate-bearing meteoric water encounters heated vapors with the resulting deposition of supergene sulfides. The combined action of the meteoric water and the hot vapors causes intense alteration of granodiorite and basalt. The resulting end product consists largely of quartz, opal, chalcedony, and clay minerals.

SOLUBILITY AND TRANSFER OF SILICA AND OTHER NONVOLATILES IN STEAM

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Recent experiments show that several nonvolatile substances are appreciably soluble in supercritical steam at pressures above 200 kg/cm². Steam at 450°C. and 304 kg/cm² dissolves 240 ppm of silica from gel. Higher pressures caused by rise in temperature increase solubility. Also, at constant temperature solubility increases with rise in pressure.

By placing various oxides or carbonates in platinum crucibles near the top of a steel bomb and water and silica gel in the bottom, silica is transferred through steam at a rate which increases with pressure and which is dependent upon the "reaction potential" between silica and the substances in the crucibles.

Kaliophilite, muscovite, pyrophyllite, wollastonite, serpentine, forsterite, brucite, and talc were synthesized. Wollastonite was formed by transfer of silica to Iceland spar. Silica and magnesium oxide formed serpentine and brucite when the temperature was below about 435°C. and forsterite and brucite when the temperature was higher. At 522°C. and 600 kg/cm² talc and forsterite were obtained. In experiments involving temperatures above 450°C. the silica gel frequently altered to euhedral crystals of quartz. If this happened transfer would be very much slower on account of a lowered reaction potential.

It may be concluded that steam at pressures above 300 kg/cm² is a powerful solvent of nonvolatiles such as silica. Pressure may be almost as important as temperature in the formation of mineral deposits by emanations.

SODIUM BICARBONATE (NAHCOLITE) FROM GARFIELD COUNTY, COLORADO*

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A notable occurrence of colorless, transparent, crystalline sodium bicarbonate, nahcolite ($NaHCO_3$), has been found in the Mahogany oil-shale bed in the Green River formation (Eocene), Garfield County, Colorado. The nahcolite was found in cavities in pods or pockets of "salt crystal" masses in the shale at a depth of 412 feet. The pockets range in size from 6 inches to 2 feet in diameter. Nahcolite occurs as crystalline masses which break easily into tabular cleavage pieces many of which show rhombic outline similar to calcite. Nahcolite is monoclinic. It has a vitreous luster. Brittle; fracture conchoidal. Cleavage in three directions; one (010) perfect, two good.

Optically the mineral is biaxial negative, $2V = 77°$ (Ca.). Dispersion is distinct, v greater than r. Cleavage pieces parallel to the perfect cleavage give a well-centered biaxial figure, showing that the acute bisectrix X is normal to or nearly normal to the cleavage. The plane of the optic axis is parallel to the perfect cleavage. The indices of refraction are: $\alpha = 1.374$, $\beta = 1.499$, $\gamma = 1.583$. $B = 209$.

This is the second verified occurrence of free sodium bicarbonate as far as is known; the first is at Searles Lake, California.

GEOLOGY OF THE BUCK HILL QUADRANGLE, TEXAS

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Green Valley on the southern Davis Mountain front in Trans-Pecos Texas was carved in Tertiary lake deposits, pyroclastics, and intercalated lava flows which rest on a basement of Cretaceous strata. These Tertiary deposits, here named the Green Valley volcanic series, are over 2000 feet thick in the Buck Hill quadrangle in west-central Brewster County. The lower 900 feet of the series is called the Pruett formation, and the upper 1000 feet, the Duff tuff. Separating these formations are basaltic lava flows up to 325 feet thick which are designated the Cottonwood Spring basalts.

The Cretaceous strata range from the Devils River limestone to the Boquillas limestone and include the Grayson and Buda formations. The basal conglomerate of the Pruett formation rests on an eroded surface of the Boquillas limestone. The Pruett tuff commonly is calcareous and locally grades to fresh-water limestone. Lava flows intercalated with the tuff, from oldest to youngest, are the Crossen trachyte, the Sheep Canyon basalts, and the Potato Hill andesite. The Duff tuff, less indurated and less weathered than the Pruett, is composed of relatively fresh silicic volcanic glass with local thick beds of stream conglomerate. It is overlain by the Mitchell Mesa rhyolite which is the youngest rock of the Green Valley volcanic series in the quadrangle.

In the southern part of the quadrangle Straddlebug Mountain and Buck Hill are small intrusives of syenite. Chemically the igneous rocks show alkalic affinities and are closely related in composition to the analyzed rocks from the Terlingua-Solitario region to the south.

The main structural features of the Buck Hill quadrangle are west- and northwest-trending normal faults. Two major fault zones divide the quadrangle into three blocks with a middle downdropped segment. Differential hardness of the rocks in the Green Valley volcanic series is the controlling factor in the physiographic development of the region. (Geological Society project.)

EARLY WISCONSIN AND OLDER DRIFTS OF SOUTHEASTERN MINNESOTA

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Limited areas of southeastern Minnesota were not covered by the last Wisconsin glaciation. Except for a small unglaciated strip near the Mississippi, these areas are covered in part by the early Wisconsin or Iowan and the older glacial drifts. All the drift sheets are patchy; none forms a con-

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tinuous mantle. In Washington County immediately north of the Mississippi River and bounded on the east by the St. Croix and in Dakota County south of St. Paul are found the greatest complexities encountered anywhere. The drift cover is thin, and considerable areas of bedrock are exposed. Soils which are reflections of glacial geology show Washington and Dakota counties as having the most complex soil patterns yet made anywhere in the United States.

Sections in both Washington and Dakota counties establish clearly the stratigraphic position of the Iowan drift. Sections showing Kansan, Illinoian, Iowan, with loess on top, are common in this area. The counties farther south present simpler relations in that no Illinoian is found.

Comparative studies of soil profiles and leaching bear out the stratigraphic relationships of the Iowan as found in Dakota and Washington counties. They demonstrate that the Iowan is more closely related in age to the Mankato than to older drifts.

CHALCOSIDERITE AND TURQUOISE

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An x-ray study of chalcosiderite from Wheal Phoenix, Cornwall, and turquoise from Campbell County, Virginia, combined with existing analyses, yields the following descriptive data:

Chalcosiderite: triclinic-pinacoidal; unit cell, with $a = 7.66$, $b = 10.18$, $c = 7.88$ kX, $\alpha = 112°29'$, $\beta = 115°18'$, $\gamma = 69°00'$, $a:b:c = 0.7525:1:0.7741$, contains $CuFe_6(PO_4)_4(OH)_8 \cdot 4H_2O$. Specific gravity, measured 3.22; calculated 3.26. Maskelyne (1875) obtained elements which, transformed to our setting, give $a:b:c = 0.7505:1:0.7703$, $\alpha = 112°18'$, $\beta = 115°18'$, $\gamma = 68°32'$.

Turquoise: triclinic-pinacoidal; unit cell, with $a = 7.47$, $b = 9.93$, $c = 7.67$ kX, $\alpha = 111°39'$, $\beta = 115°23'$, $\gamma = 69°26'$, $a:b:c = 0.7523:1:0.7724$, contains $CuAl_6(PO_4)_4(OH)_8 \cdot 5H_2O$. Specific gravity, measured 2.84; calculated 2.95. Schaller (1912) retained Maskelyne's chalcosiderite elements for turquoise.

GEOLOGY OF A PART OF THE MINNESOTA SHORE OF LAKE SUPERIOR NORTHEAST OF TWO HARBORS, MINNESOTA

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The rocks exposed along the shore of Lake Superior for 16 miles northeast of Two Harbors consist of Middle Keweenawan lava flows and minor associated sediments of the Keweenaw Point volcanic series together with a number of diabase intrusives belonging to the Beaver Bay complex. The flows have an average strike of N. 40° E. and a southeasterly dip generally less than 10°. Structural deformation is confined to gentle warping and minor faulting except in the vicinity of the major intrusives. The stratigraphic thickness of the exposed bedrock including an estimate for intervals of no outcrop is 3800 feet, of which 3207 feet is in addition to the thickness of the Keweenawan series previously measured to the southwest by Sandberg and to the northeast by Grout and Schwartz.

The 70 recognized flows, of which 68 are basaltic, one acidic, and one partly of intermediate composition, have an aggregate thickness of 3295 feet. The sedimentary rocks are interflow sandstones, amygdaloidal conglomerates, a scoriaceous amygdaloid breccia, and clasolites. The intrusive rocks include four major sill-like masses of fine- to coarse-grained diabase, five basic dikes, and one pipelike mass. The pipelike mass is filled with coarse basaltic fragments in a matrix consisting of fine breccia and a little intrusive basalt. It is suggested that the pipe was formed by the explosive release of gases during the cooling of closely underlying magma, and that the resulting release of pressure aided the formation of the vesicles observed in the upper parts of the nearby sills.

TRIASSIC GASTROPOD FAUNA FROM CERRO DE PASCO, CENTRAL PERU

OTTO HAAS

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Extensive collections of Mesozoic invertebrates, made some years ago by Dr. William F. Jenks in the region about Cerro de Pasco, are now being studied in The American Museum of Natural

History, within the scope of a wider program planned to cover the Mesozoic stratigraphy and paleontology of Peru.

Most of the fossils are silicified and can readily be extracted from the rock by chemical preparation.

Among the gastropods a few forms seem to be new and might necessitate the establishment of new genera. Most of the other forms, as well as the assemblage on the whole, strikingly resemble certain faunas of the European Alps, *e.g.*, the renowned St. Cassian fauna. This similarity would suggest a Ladinian (Upper Middle Triassic) age, but the supposedly Triassic fossils under study might well cover a wider than Ladinian stratigraphic range.

FEATURES OF GEOLOGIC STRUCTURE ON THE BLUE RIVER-SOUTH PLATTE TRANSMOUNTAIN DIVERSION LINE

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A major Bureau of Reclamation project in the Rocky Mountains area is the Blue River-South Platte Transmountain Diversion Plan to divert water from the Blue River and adjacent watersheds into the South Platte River on the eastern slope of the Colorado Front Range.

The principal engineering features proposed for this project include a tunnel 18-20 miles long beneath the Continental Divide; three dams; several miles of canals tapping streams tributary to the Blue River; the Gore Conduit which requires several short tunnels with connecting canals; and another tunnel, 7–8 miles in length, beneath Vail Pass.

Salient features of geology on the proposed construction are two large thrust faults: (1) the Williams Range thrust, which is exposed along the east side of the Blue River Valley; (2) the Gore thrust which extends northwestward beyond the limits of the catchment area. The Williams Range fault, where schists and gneisses of the Idaho Springs formation (pre-Cambrian) have been thrust over Pierre shales (Cretaceous), lies directly athwart any feasible tunnel route connecting the Blue River drainage with the South Platte. The Gore thrust, where granite and gneiss (pre-Cambrian) overlie Maroon redbeds and limestones (Pennsylvanian), extends transversely with respect to the Vail Pass tunnel line and will also be encountered in shorter tunnels along the Gore Conduit.

ARROYO PROBLEM

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The channels of intermittent streams are being enlarged by incision and widening throughout large parts of the United States. In the Southwest this has been recognized as the "arroyo problem," involving extensive damage to grazing and irrigated lands and increased sedimentation in major valleys and reservoirs, and there has been controversy as to whether the cause is climatic change or depletion of protective vegetation by overgrazing. This is of more than academic interest, for large Federal expenditures are advocated on the basis of the theory of grazing control. Less well known is similar enlargement of intermittent stream channels in many places from central Texas to Nebraska, Minnesota to Mississippi and North Carolina, and from central Ohio to Virginia. The only apparent difference is the size of individual arroyos; those of the Southwest are larger because the streams of intermittent flow are longer. There are indications of former cycles of erosion and alluviation in the more humid regions as in the Southwest, but in all areas channel erosion has become prominent since agricultural development. The similarity in conditions calls for a similar explanation, either climatic change throughout most of the United States or increased erosional runoff and decreased vegetative protection, as the cause in the Southwest as well as elsewhere. The latter theory appears to be more reasonable, for surely natural vegetation in the more humid States is not now severely depleted because of a climatic change.

ELECTRICAL-RESISTIVITY INVESTIGATIONS OF LEVEE FOUNDATIONS NEAR KANSAS CITY

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Electrical resistivity surveys have been made for investigation of foundations for two levee units of the Kansas City flood protection project, located in the alluvial flood plains of the Kansas and Missouri rivers. Specific resistivity measurements on 270 subsurface samples, obtained by drilling, show general agreement with the accepted principle that resistivity increases with grain size, but the variation in resistivity of materials of similar textural classification is greater than the average difference in resistivity for different standard textural classes. The resistivity of sand from below the water table is also much less than that of finer materials from above the water table. "Vertical resistivity profiles" measured at 24 drill holes give reliable indications of the depth of contact of surficial sands on fine-grained impermeable strata, but are not reliable for determining the contact of these impermeable strata on underlying sands, or for tracing the extent of individual clay layers within a variable complex of silty and sandy beds. Equally consistent interpretations are obtained by comparison with Wetzel's theoretical three-layer curves, or by the tangent method described by Moore. Faster "step-traverse" surveys are apparently reliable for verifying the continuity of surficial fine-grained impermeable strata overlying sands, but drilling is necessary to determine the thickness of the impermeable strata and for interpretation of resistivity variations. Neither methods of survey nor of interpretation give consistent results where measurements were made on existing levees, including heterogeneous industrial waste materials, resting on alluvial sands.

SEDIMENTATION IN THE MIDDLE RIO GRANDE VALLEY

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Surveys showed sediment accumulation at a rate of 12,000 acre-feet or 21.5 million tons per year from 1936 to 1941 in the Middle Rio Grande Valley, above Elephant Butte Reservoir in central New Mexico. Nearly two-thirds was concentrated in the lower 17 miles of the Valley, largely because of headward growth of the Reservoir delta, although Rio Grande aggradation began prior to Reservoir construction. Throughout most of the upper 133 miles low levees confined sedimentation to a restricted floodway, which was aggraded at a rate of 0.08 foot per year, by sedimentation on the berms without significant net change in average river bed elevations. This was probably a temporary relationship due to flood scouring shortly before the 1941 resurveys, as water surface records indicate river aggradation from 1917 to 1936 at about the same rate as the 1936–1941 floodway aggradation. The high rates of sedimentation are obviously caused by channel erosion in the alluvium of tributary valleys, probably as a result of depletion of natural vegetation by excessive grazing since 1870. Aggradation seriously threatens the future of irrigation, drainage, and flood protection works essential for more than 100,000 acres of irrigated lands, a major part of the city of Albuquerque, and numerous smaller communities. An effective remedial program will require both major sediment detention structures, for positive and prompt control, and some system of arroyo stabilization to retard erosion throughout the grazing lands and thus extend the useful life of the major structures.

ENGINEERING GEOLOGY OF THE ALVA ADAMS TUNNEL, COLORADO-BIG THOMPSON PROJECT, COLORADO

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Three tentative routes for the Alva B. Adams Tunnel from Grand Lake to Estes Park showed no essential differences in geology in the preliminary study. The southern route was chosen because the engineering aspects were most favorable. During construction, a detailed surface study was

made of 7 miles of the tunnel line, and a careful record was kept of the geology exposed in the tunnel along its entire length of 13.1 miles. The progress record was supplemented by reports comparing surface and tunnel geology.

The kinds and proportionate amounts of rock and their physical conditions were quite successfully predicted although the tunnel was driven through a complex of pre-Cambrian metamorphics invaded by dikes, sills, and large bodies of Longs Peak granite. A relationship between structures on the surface and at tunnel grade was recognizable although faults and narrow shear zones were not identifiable at depth. One exceedingly bad zone of wet and squeezing ground affected 386 feet of tunnel and required heavy support for 255 feet and very heavy support for 21 feet. The zone was profoundly sheared and altered; hornblende altered to chlorite, and feldspars to clay. The worst part of the corresponding zone at the surface was covered by overburden.

Associated schists presented more unfavorable tunneling conditions than the predominant gneisses and granites because faults and joints in combination with the schistose structures caused "blocky" ground and "overbreak", etc. Water occurred in comparatively small quantities and always in the "blocky" ground.

AEROMAGNETIC PROSPECTING

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Aeromagnetic measurements have been made for purposes of (1) scientific exploration, (2) determination of pole depths of magnetite deposits, (3) submarine location, and (4) prospecting for oil and ore. Instrumentation, approached from various directions, included the use of (1) single or coupled magnets; (2) stationary or rotating coils; (3) magnetrons, and (4) saturated core reactors. The latter found many uses during the war in aircraft compasses, mine fuzes, degaussing, and submarine detection. Although submarine locators can be modified for prospecting, it appeared preferable to design equipment specifically for this purpose, resulting in improvements such as (1) reduction in size, (2) wing-tip installation, (3) compensation for changes in the ship's permanent and induced magnetism with course, roll, pitch and yaw, (4) synchronized registration of terrain photographs and magnetic readings, and (5) position fixing by radar triangulation. Together with time, radio altitude, radar fixes, record number, and magnetic range, magnetic readings appear on a photo panel which for abnormal gradients is supplemented with a continuous recorder. Operational procedure includes (1) determination of approximate magnetic strike parallel to which a base line is flown to fix magnetic and geodetic references; (2) flight profiles at right angles to strike, spaced according to strike variations in geologic detail. Magnetic values, corrected for diurnal variation, base drift, and planetary changes, and plotted against position fixes, are represented as contour maps or profile curves and are interpreted qualitatively or quantitatively by conventional analytical, graphical, or model techniques. Aeromagnetic reconnaissance has the advantages of (1) speed, (2) ability to cover inaccessible areas, (3) attentuation of man-made and topographic effects, and (4) interpretational advantages arising from flying at different altitudes.

PROCURING ECONOMIC DATA IN OCCUPIED COUNTRIES*

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In the procuring of data on economic geology three basic factors must be considered: the purpose of procuring data; the data required to achieve those aims; and the methods to be employed. The following comments will apply to Japan and Korea.

The purposes of the work in general were: re-establishment of the mineral industries at the maximum level consistent with the aims of the occupation; integration with related industries; determination of reasonable reparations from mineral industry plants and equipment; furthering of export of mineral products to impoverished countries such as the Philippines; providing of adequate intelligence data for future Allied purposes.

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The data required were, in general terms: the quantity and quality of past production in detail; existing plant facilities and developed reserves; total reserves and production potentialities; information concerning new or unusual methods and materials.

The methods employed in obtaining data were: compilation in the United States; compilation from published records in the occupied country, assembling from Government agencies and control associations, assembled from commercial companies and from individuals, assembling from universities and research institutions. After compilation of all available data a field check was made by Allied technical personnel, generally assisted by qualified technical men of the occupied country.

The assembled information was consolidated into a series of reports that were largely economic in nature. They contained abundant factual and statistical data and an analysis of the factors of economic importance.

PROPOSED CONTINENTAL SHELF PROGRAM, U. S. GEOLOGICAL SURVEY*

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U. S. Geological Survey, Washington 25, D. C.

The Geological Survey is preparing plans for a 15-year program of study of the Continental Shelf of the United States and Alaska. Work for the first 5 years will be largely concentrated in the Gulf of Mexico because of the likelihood of extensive petroleum reserves there.

The work will be both geological and geophysical. Geological work will be divided into two parts: subsurface studies of the outer belt of the Coastal Plain; and collection and study of bottom and water samples and cores of the sea floor. These studies will supply basic data and aid in interpretation of geophysical data.

The geophysical work will be by adaptation of standard geophysical methods. Complete gravimetric and magnetic surveys will be made. Seismic work will consist of profiles carried from the shore to the edge of the Continental Shelf. Both reflection and refraction shooting will be done with the choice of the method being determined by local and regional geologic factors. Most of the geophysical work will be done on contract.

The work will be conducted so as to provide data of regional scope and will serve as a basis for more detailed studies as desired.

BATHYMETRY AND GEOLOGIC STRUCTURE OF THE WESTERN NORTH PACIFIC

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During the war the Navy accumulated a vast number of soundings in the Pacific Ocean. Many sounding lines crossed areas far from normal shipping routes and in waters seldom traversed by ships. Combining these soundings with those already existing on Pacific charts it was possible to construct far more accurate and detailed bathymetric charts of the area than heretofore. The first of these charts to be printed by the Hydrographic Office U. S. Navy covers the area from Korea to New Guinea including within it the Marianas, the western Carolines, the Philippines, the Ryukyus, southern Japan, the Bonins, and the Volcanoes.

The great elongate, deep trenches form the most striking topographic and structural features on the chart. The deeps are much more continuous than was previously indicated. East of the deeps from Japan to Palau a portion of the North Pacific Basin Province is portrayed which differs markedly in topography, structure, and petrology from the island-arc provinces to the west. The so-called "Andesite Line" separates the North Pacific Basin province from the western island-arc provinces. The concave side of the curved deeps contains from one to three parallel geanticlined swells on which volcanic islands are characteristic.

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The vulcanism and seismic activity of the area are discussed. The geologic history of the region is outlined insofar as it may be surmised from fragmentary data. In general the eastern and southern belt of arcs and mountains is related to Late Cretaceous-Early Tertiary deformation which has continued spasmodically up to Recent time, whereas a western belt including southern Japan, the Ryukyus, Formosa, and the western Philippines is probably the product of mid-Mesozoic deformation.

"NEBRASKAN" AND "KANSAN" GLACIAL LOBES IN IOWA

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The approved glacial history of Iowa takes account of no lobes of its earlier Pleistocene glaciations, these being assumed to have blanketed the entire State. Their deposits have been described as "drift", deposited by the ice directly.

Studies of the periglacial area of the Greenland glacier have revealed surrounding aprons of glacio-fluvial and glacio-eolian deposition, and identifying criteria for each class—till, outwash, and loess.

Applying these criteria to the Iowan deposits from the two earlier glaciations, glacial till is found to be restricted to two concentric lobes, one above the other, in the southeastern quarter of the State. Both glaciers invaded Iowa from across the Mississippi in Illinois and extended westward, the earlier one to Des Moines, the later as far only as Eddyville. Each in its turn diverted the waters of the Mississippi in channels cut deep in bedrock and now filled with outwash largely from the later Illinoian and Wisconsin glaciers. These channels, respectively 405 and 330 miles in length, return, and through estuaries the earlier joins the Missouri below Franklin, the later the Mississippi below Keokuk.

Subsequently there entered the State from the north two lobate glaciers, the latest the well-known Mankato lobe of Late Wisconsin age, and beneath and around it a hitherto unrecognized Mankato lobe of Late Illinoian age. All other glacial deposits of the State, excepting those of a slight Illinoian invasion from the east, are either glacio-fluvial or glacio-eolian in origin.

ASYMMETRIC DISTRIBUTION OF MORAINAL DEPOSITS IN THE PLATEAU VALLEYS OF NEW YORK

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Along the Valley Heads moraine through central New York the end-moraine deposits in the individual north-south valleys have a general asymmetric distribution with respect to the valley axes. This asymmetry is best observed in the valleys of relatively small or medium size such as Onondaga, Otisco, and Skaneateles valleys, though it is apparent also at the heads of the larger valleys. The morainal loops are higher and better-developed on their eastern sides than on the western. The trend of the moraines is somewhat diagonally southwestward across the valleys, bringing the limits of the moraines farthest south at some point west of the valley axes. Outwash-plain surfaces bordering the western parts of the loops have more kettles and associated collapse features than are shown by corresponding surfaces near the eastern sides. These characteristics are believed to indicate that, during deglaciation, strong afternoon insolation induced comparatively rapid and complete melting along the eastern sides of the valley lobes with corresponding concentration of outwash there, the outwash gradually encroaching on the stagnant or stagnating ice partly shaded by the steep western valley walls.

Comparable features south of the limits of the Valley Heads glacial lobe show that similar conditions attended deglaciation of the region also at the close of the preceding glacial substage.

PLEISTOCENE DEPOSITS BELOW THE WISCONSIN DRIFT IN ILLINOIS*

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Data provided by about 510 sets of well cuttings, 730 drillers' logs, and 125 exposed sections show that Sangamon, Illinoian, Yarmouth, and Kansan deposits are essentially continuous below the outer portion of the Wisconsin drift sheet. They occur in a peripheral zone 25 to 100 miles wide, which extends southward from the Wisconsin line into central Illinois and thence eastward into Indiana. Possible remnants of Aftonian soil and Nebraskan till are preserved along the flanks of major bedrock valleys in the southern part of the area. An extensive fill of sand and gravel up to 300 feet thick within the ancient Mississippi (middle Illinois) bedrock valley is termed the Sankoty sand, and a similar deposit within the Mahomet (? Teays) bedrock valley is called the Mahomet sand. These valley deposits, which locally underlie Kansan and probable Nebraskan tills, may reflect the initiation of glacial conditions and are tentatively considered Nebraskan in age.

The widespread preservation of the Sangamon soil and weathered zone below Wisconsin drift in a peripheral belt and the absence of older drift to the northeast indicate that the Wisconsin ice actively eroded only within an inner zone margining Lake Michigan.

CALICHE IN GLACIAL CHRONOLOGY

ARTHUR D. HOWARD

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Studies in northwestern North Dakota and northeastern Montana indicate that depth of leaching may have little value in determining glacial chronology in arid and semiarid climates. In much of the area studied, evaporation draws water and included salts surfaceward by capillarity. The salts, primarily calcium carbonate, are deposited in a white caliche zone up to several feet thick, in which the concentration and compactness are greatest toward the sharp upper boundary. The lower boundary of the zone is transitional. Carbonate reaction has been obtained consistently from the underlying material, indicating imperfect leaching. The existence of an inverse leaching profile, however, could not be established. The surfaceward movement of lime carbonate in the area studied suggests that variations in depth of leaching in regions which extend across both humid and arid climatic zones may reflect climatic rather than chronologic differences.

Under favorable conditions, the thickness of caliche zones and of caliche coatings on the undersides of pebbles may increase with time. Studies of glacial deposits in northwestern North Dakota and northeastern Montana have not as yet revealed appreciable differences in drifts which have been assigned different ages. This may mean (1) that the deposits do not differ as widely in age as heretofore assumed, (2) that the caliche method, because of the many variables involved, is not reliable enough for such determinations, or (3) that the study has not been carried far enough to justify any conclusions. In deference to the last possibility, the investigation is to be continued.

LATE WISCONSIN TERMINAL MORAINE IN NORTHWESTERN NORTH DAKOTA

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Fort Union beds, including coal, are exposed locally at and near the crest of the so-called Altamount terminal moraine in northwestern North Dakota. The topographic prominence of the moraine in this area may, therefore, be due to a high in the bedrock surface rather than to an unusually thick accumulation of drift. The Fort Union exposures are overlain by gravels identical in lithology and

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appearance with the Flaxville gravels which cap mesalike remnants of a high-level surface farther west in Montana. The bedrock prominence over which the late Wisconsin ice rode may represent a dissected, eastern outlier of this surface.

South of the so-called terminal moraine, other morainal areas with numerous closed depressions lie at lower elevations than immediately adjacent Late Wisconsin outwash. The improbability that closed depressions could have been exhumed from under outwash suggests that ice occupied the morainal areas while the outwash was being deposited and that these moraines are also of Late Wisconsin age. It is concluded that Late Wisconsin ice locally extended farther south in this region than previously supposed.

TUBICOLOUS ANNELID GENUS *Spirulaea* (*Tubulostium* OF AUTHORS) IN EOGENE OF COASTAL PLAIN

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Spirulaea was proposed by Bronn in 1827 for the worm genus which has been called by more recent authors *Tubulostium*. *Spirulaea rotula* (Morton) from the Vincentown formation of New Jersey, *S. mcglameryae* (Gardner) from the Sucarnoochee formation of Alabama, *S. tobar* (Gardner) from the Kincaid and Wells Point formations of Texas, *S. horatianum* (Gardner) and *S. leptostoma* (Gabb) from the Eogene of Texas, and two undescribed species, one from the Salt Mountain formation of Alabama and the other from the Cook Mountain formation of Texas, are recognized as American species of this genus. *S. mcglameryae* and *S. tobar* are good Paleocene (Midway) index fossils, *S. rotula* and *S. horatianum* are restricted to Lower Eocene (Wilcox) beds, and *S. leptostoma* is found only in Middle Eocene (Claiborne) deposits. *S. mcglameryae* has been found in a well in Virginia, indicating that there are buried Paleocene (Midway) beds in that state, and *S. rotula*, heretofore known only from the upper "limesand" portion of the lower Eocene Vincentown formation of New Jersey, has also been secured from deposits in a Virginia well that are believed to lie in the upper part of the Aquia formation and are probably not exposed at the surface.

DEVONIAN AND MISSISSIPPIAN ROCKS OF CENTRAL ARIZONA*

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The Upper Devonian rocks of central Arizona are placed in the Martin formation and divided into a lower member composed of dolomitic limestone and conglomeratic sandstone, a middle member of sandstone and cliff-forming limestone, and an upper member of sandstone, sandy limestone, and shale. Stromatoporoid and coral bioherms are common in the middle and upper members. The formation becomes increasingly sandy westward in central Arizona and thins abruptly against a cliff of Cambrian Troy quartzite near Grasshopper in the western part of the Fort Apache Indian Reservation. The increase in sandiness and the abrupt thinning is due to the approach to Mazatzal Land, a northeast-trending residue of pre-Cambrian mountains extending from southwestern Arizona through the Defiance uplift to southwestern Colorado. Near the Mogollon Rim there were three prominent ridges on Mazatzal Land. These ridges formed peninsulas, islands, or rocky reefs in the Devonian sea, and immediately north of them a low gap in Mazatzal Land, the Mogollon sag, permitted the Upper Devonian seas to the northwest and southeast of Mazatzal Land to join. A Paleozoic basin in the Black Mesa area lies on the north side of the Holbrook granite ridge, a buried portion of Mazatzal Land; and a basin southeast of the ridge is probable.

The Mississippian Redwall limestone consists of a lower impure dark-gray limestone, a middle massive cliff-forming limestone, and an upper thin- to medium-bedded cherty limestone. The limestone thins greatly on Mazatzal Land but is traceable from Tornado Peak to Fossil Creek,

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demonstrating that the Redwall and Escabrossa limestones represent a continuous mappable unit. The thinning of the Redwall limestone on Mazatzal Land is due largely to pre-Pennsylvanian erosion which developed caves and sink holes in the limestone, a rubble breccia of limestone and red sandy mudstone, and thick residual soils and chert breccia. The residual soil and breccia were partly reworked by the encroaching Pennsylvanian sea to form the basal red sandy mudstone member of the Pennsylvanian Naco formation. This member was formed in the same manner as the Molas formation of Colorado and is correlated with it.

IMPROVED APPARATUS FOR DOUBLE-VARIATION PROCEDURE

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In working with the double-variation method for refraction-index determination as proposed by Emmons, several difficulties are encountered which somewhat complicate the procedure. These are chiefly the inability to control the temperature accurately; the collection of bubbles in the water cell on the stage; and the necessity of using an arc light for illumination. The first two difficulties have been eliminated by constructing a simple recirculating system in which a small volume of water free from air is used continuously. The temperature of this water is controlled by a thermostat that can be adjusted for any predetermined value.

An arc has been necessary so that monochromatic light of sufficient intensity could be obtained with a monochromator. A new type of transmission-interference filter is now available which enables one to obtain light of a given wave length of high intensity using a lamp with an incandescent filament.

LIQUID INCLUSIONS IN GEOLOGIC THERMOMETRY

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Most vein minerals and many of those in igneous rocks contain liquid inclusions. A satisfactory method of determining temperatures of crystallization from the liquid inclusions would aid in the solution of many problems of geologic thermometry.

Recent data on the specific volume of water at high temperatures and pressures allow much more accurate determination of the effect of pressure than has been possible before, and data on the critical temperatures of aqueous solutions of alkali halides provide the basis for better evaluation of the effect of concentration.

Curves have been prepared showing the relation of degree of filling of inclusions and temperature of disappearance of the vapor phase, both for pure water, and for a 10 per cent solution. A series of curves shows the relation between temperature of disappearance of the vapor phase, pressure at the time of formation, and temperature of formation.

For vein and pegmatite quartz studied, where pressures can be estimated from the amount of overburden at the time of formation, pressure corrections range from about 45° to 90° C.

CAUSE AND AGE OF PLEISTOCENE ENTRENCHMENT IN THE OHIO AND LAKE ERIE BASINS

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Entrenchment within the area described has been attributed previously to regional uplift, elastic rebound after deglaciation, increase in gradients due to reduction of channel lengths, and enlargement of drainage basins by stream diversion. The age of the major entrenchment, called the Deep Stage, has been assigned previously to the Yarmouth interglacial epoch. None of the causes for entrench-

ment heretofore suggested can account for differential entrenchment in disconnected basins, periodic entrenchment, or accordant entrenchment in nonglacial valleys tributary to outwash channels.

It is believed that entrenchment in most valleys was additive for more than one epoch and that degradation was early glacial and not interglacial. The volume of material removed appears excessive to have been removed during a single epoch. Increased gradients due to lowering of sea level during glacier advance accompanied by increased southward drainage of rainfall south of the ice area are believed to have caused the entrenchment. Increased rainfall probably resulted from greater interaction of Polar Continental air masses along the moving ice front when they were crowded southward against Tropical Marine air masses. Degradation started early during each glacial period when sea level began to drop and continued until deglaciation initiated aggradation.

Assuming that climatic conditions were similar for each glacial epoch entrenchment should have occurred during the early part of each epoch. Early Wisconsin and early Illinoian entrenchment are proven in many areas. Some valleys show entrenchment attributable only to Nebraskan or Kansan or both. In most valleys entrenchment was additive during the Nebraskan, Kansan, and early Illinoian until the major drainage changes of the Illinoian disrupted the systems. The Deep Stage was a result of several epochs of entrenchment culminating in early Illinoian and was not exclusively Yarmouth.

ENGINEERING GEOLOGIC PROBLEMS OF THE GRAND COULEE AREA, COLUMBIA BASIN PROJECT, WASHINGTON

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Co-ordinated surface geologic investigations, subsurface exploration, and laboratory studies, begun several years ago in the Columbia Basin area by the Bureau of Reclamation and still in progress, are reviewed. The nature of the engineering geologic problems encountered in selecting reservoir sites and in locating and supplying geologic data required for the design of the dams, tunnels, siphons, canals, and related engineering structures is outlined.

Maps and cross sections of surface geology and subsurface structure and detailed drill records are supplied, together with data and interpretations of glacial deposits, structure and petrology of the basalt flows, and ground-water conditions. Descriptions are provided of the salient geologic features at the proposed sites of North Coulee Dam, South Coulee Dam, Upper Grand Coulee Equalizing Reservoir, and Soap Lake Siphon in the Lower Grand Coulee. The more important data derived from supplementary studies in adjacent areas are discussed.

The study and interpretation of these data for engineering purposes have involved consideration of local as well as regional geologic problems and have aided in developing and clarifying the geologic history of this area. The results are being made available for use by other geologists who have or may wish to initiate special research studies in the Grand Coulee area.

GEOLOGY AND GROUND-WATER HYDROLOGY OF THE SOUTH DAM, COLUMBIA BASIN PROJECT, WASHINGTON

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The South Dam, a feature of the Columbia Basin Irrigation System, will extend across the southern end of the Upper Grand Coulee near Coulee City, Washington. The reservoir area is underlain chiefly by basalt flows with a slight regional dip to the southwest; exposures of Colville granite occur in the northern section of the proposed reservoir. The Coulee monocline borders the lower end of the reservoir on the northwest and crosses it obliquely about 2 miles north of the damsite. The monocline is faulted where it crosses the reservoir and is flanked on the southeast by an open syncline with axis plunging to the northeast beneath the Hartline Basin.

As the reservoir is filled the adjacent ground-water tables will rise, and some ground water, now tributary to the reservoir area, will be diverted to areas below the dam. Seepage losses from the reservoir through and beneath the earth dam will move toward the Dry Falls area and Lower Grand Coulee. Estimated losses beneath and through the dam will be relatively small and will be dissipated largely by evaporation and transpiration. In view of the relatively small seepage losses anticipated, grouting may be limited to the shallow depths required to seal the upper weathered and permeable zone of the foundation rock. An extensive program of ground-water and surface-water observations has been started to determine the effect of the filling of the reservoir on ground-water levels and movements and to aid in locating paths of seepage.

LITHIUM-TANTALUM PEGMATITES IN MORA COUNTY, NEW MEXICO

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Several small pegmatite dikes that contain appreciable quantities of lithium and tantalum minerals are exposed on the steep eastern slope of the Sangre de Cristo Range in southern Mora County, New Mexico. One of these dikes, known as the Pidlite, has yielded small quantities of microlite and several hundred tons of lepidolite since it was opened up in February 1946. It contains an assemblage of minerals strikingly similar to that of the Harding pegmatites in Taos County, New Mexico, and to that of the Brown Derby pegmatites in Gunnison County, Colorado, and it may well be the southernmost representative of a clearly defined lithium-rich pegmatite province in the Southern Rocky Mountain region.

The dike is 75 feet long, 16 feet in maximum width, and has been mined to a depth of more than 35 feet. It strikes north-northeast and dips very steeply in fine-grained amphibole schist. Lepidolite ore, which occurs between the west wall of the dike and a riblike core of massive quartz, constituted nearly two-thirds of the pegmatite at its outcrop. It is associated with cleavelandite and quartz and appears to have been formed by replacement of granitoid microcline-rich pegmatite. The lepidolite is gray to deep lilac and ranges from tiny flakes to thick plates 2 inches in diameter. Other minerals in the dike include amblygonite, apatite, beryl, betafite, bismutite, cyrtolite (?), fluorite, gadolinite (?), hatchettolite, monazite, muscovite, spessartite, spodumene, tantalite-columbite, topaz, and tourmaline. Many of these also occur in pegmatite elsewhere in the area but in general are not well exposed.

MIDDLE AND UPPER PENNSYLVANIAN LOPHOPHYLLIDID CORALS

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Lophophyllidid corals comprise solitary conical and conico-cylindrical corallites having an axial column developed in part by a thickening of the counter septum, shortened cardinal septum, tabulae but no dissepiments, and well-defined septal grooves. These corals occur in a larger proportion of Pennsylvanian deposits than in other types of corals, and they seem to be especially useful in stratigraphic paleontology.

The family Lophophyllidiidae Moore and Jeffords (1945) is recognized to include *Lophophyllidium* Grabau (1928), *Lophocarinophyllum* Grabau (1922), *Malonophyllum* Okulitch and Albritton (1937), *Lophamplexus* Moore and Jeffords (1941), *Lophotichium* Moore and Jeffords (1945), *Claviphyllum* Hudson (1942), *Kinkaidia* Easton (1945), *Fasciculophyllum* Thomson (1883), and a new genus. These genera are illustrated and described briefly, and a key is included for the differentiation of lophophyllidid genera. Consideration is given to the morphology, ontogeny, and phylogenetic development of these corals. Also, graphic representation of variation in several characters indicates that statistical treatment of quantitative data is useful in the rigorous comparison of lophophyllidid faunas.

Late Paleozoic lophophyllidid corals which have been referred generally to *Lophophyllidium* (*Lophophyllum* of authors) are shown to include several distinct genetic types, each characterized by a combination of several characters. *Lophophyllidium* (syn. *Sinophyllum* Grabau, 1928) is restricted to species having a large axial column that contains radiating laminae and septa that are not shortened in maturity. Corals in which lophophyllidid characters are restricted to the immature region and resemble *Amplexus* above are assigned to *Lophamplexus*. A new genus is proposed to include those species characterized by a relatively smaller and laterally compressed column that lacks radiating laminae and by a marked reduction in the length of major septa in maturity. A total of 24 species is described, and 7 species are referred to *Lophophyllidium*, 7 species to *Lophamplexus*, and 10 species to a new genus.

TERTIARY AND QUATERNARY VULCANISM IN SOUTHERN PERU

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Volcanic sequences which aggregate up to 5000 meters cover the Pacific-Titicaca divide and adjacent areas of southern Peru. In the Departments of Tacna, Moquegua, Puno, and Arequipa east of the seventy-third meridian, at least 58,600 square kilometers is underlain by volcanic material. Two distinct series are recognized: the older basaltic to andesitic Tacaza volcanics, of probable Pliocene age, and the Sillapaca volcanics, chiefly of andesitic or more silicic composition, of late Pliocene to Recent age. It is believed that the Tacaza volcanics are to be correlated with the Rio Blanco volcanics of central Peru. The Tacaza is in many places strongly folded and faulted, whereas the Sillapaca volcanics are structurally undisturbed except in a few zones of late deformation. The Tacaza volcanics are flows and pyroclastics in beds 3 to 30 meters thick which may be traced many kilometers; eruptions appear to have been largely of the plateau type, but several truncated, breccia-filled vents apparently of this age are known. The Sillapaca volcanics are provisionally considered as including all volcanics resting unconformably upon the eroded Tacaza and older formations. They include widespread lava flows and pyroclastic beds, as well as products of numerous central eruptions. Several volcanoes active within historic times are tentatively grouped with the Sillapaca.

An important component of the Sillapaca volcanics is tuff of the Pelean type (locally known as sillar), which covers an area of 450 square kilometers northwest of Arequipa, and is also important in the southwest part of Cuzco Department, in the southern part of Apurimac Department, and all along the eastern edge of Arequipa Department. The local succession of beds at the west base of Chachani, a multiple volcanic center north of Arequipa, is: (1) sillar; (2) alluvial gravels; (3) basalt flows; and (4) andesite flows.

Most of the Sillapaca volcanics, including the great volcanoes and the broad, high reaches of flat-lying volcanics, show marked effects of Pleistocene glaciation, but some of the volcanics, especially those making up andesitic cinder cones in the Andagua valley and low, small basalt cones south of Caylloma, are postglacial. Marked changes in the course of the Chili River were produced by the growth of the volcanoes Chachani and El Misti. Correlation of late volcanic events with three well-developed erosion surfaces in the Arequipa and Vitor regions is demonstrated.

FIELD CHECKING OF TERRAIN INTELLIGENCE REPORTS*

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During the later phases of World War II and after V-J Day a number of members of the Military Geology Unit of the U. S. Geological Survey have had the opportunity to check in the field some of the terrain-intelligence reports prepared by the Unit during the war for the U. S. Corps of Engineers.

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The field checking has been done in varying degrees of detail, depending on the amount of time and transportation available. Areas that have been visited are Leyte, Samar, Panay, and Luzon in the Philippine Islands; Okinawa; Korea; and parts of Kyushu, Honshu, and Hokkaido in Japan.

In general, there is good agreement between the statements made in the folios and situations as found in the field, justifying the confidence placed by compilers of terrain-intelligence reports as a basically important source of information.

MIDDLE ORDOVICIAN LIMESTONES IN SOUTHEASTERN WEST VIRGINIA AND ADJACENT VIRGINIA

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Middle Ordovician between Monroe and Pendleton counties, West Virginia, through Craig, Alleghany, Bath, and Highland counties, Virginia, has Blackford and Five Oaks limestones at the base. The dark cherty Lincolnshire limestone thins from 150 to 30 feet northeastward and has local coralline bioherms like those in lowest Valcour in Vermont. The Hatter formation, 400 feet of argillaceous Ward Cove, cherty Perry and biohermal Benbolt limestones in the southwest, thins to 160 feet, principally Benbolt, at the northeast; Ward Cove simulates Eyer of southern Pennsylvania, Benbolt, the Grazier and Hostler; faunas resemble higher Valcour, perhaps partially synchronous with Pamelia. The Benner formation has about 100 feet of Snyder (Gratton) and Stover (Witten) limestones converging and offlapping to absence southeastward; rather constant lithology from Virginia to north-central Pennsylvania and similarity to Lowville and Chaumont in New York suggest equivalence, contrary to previous faunal interpretations. The Curtin formation has not been recognized in the Virginias.

Lower Trenton beds in the southwest are Moccasin reddish calcargillutites, about 200 feet, below Eggleston quartz fine sandstone, buff argillutite and calcilutite with metabentonites V-3 to V-6, about 70 feet; some have included the succeeding Cuneiform zone. The Moccasin becomes buff and white argillutite and calcilutite northeastward; typical Eggleston persists to central Alleghany County, approximating Collierstown and St. Luke limestones farther southeast. Northeastward, Nealmont shaly limestone, calcilutite and calcarenite, seems equivalent to Moccasin and most of the Eggleston; succeeding lower Salona (Greencastle) persists to northernmost Alleghany County, terminated by metabentonite 2, apparently in the stratigraphic position of V-6. Middle Trenton limestone overlies.

DIFFERENTIAL THERMAL ANALYSIS OF MISSOURI FIRE CLAYS

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Mineralogical determinations by the thermal-analysis method were made of a wide variety of Missouri fire clays and the clay fractions of several other argillaceous sediments. The common hard flint fire clay gives a typical kaolinite curve, but the so-called "soft flints" show both endothermic and exothermic reactions at slightly lower temperatures than does kaolinite. Some plastic fire clay is dominantly kaolinite, but curves of other varieties indicate mixtures, possibly montmorillonite with kaolinite. The high-alumina clays contain kaolinite, diaspore, gibbsite, and boehmite.

A clay from loess is illite, and clays from shale suspensions give illite and kaolinite reactions. Comparative curves of the clays are shown.

GUIDE FOSSILS OF THE MIDDLE JURASSIC TUXEDNI SANDSTONE, ALASKA

L. B. KELLUM AND MARILYN NORTON

University Museums, Ann Arbor, Michigan

Numerous sections of Jurassic strata were measured along Cook Inlet and the Alaska Peninsula during the field seasons of 1944 and 1945 in connection with the petroleum investigations of the United States Geological Survey. Large collections of marine invertebrate fossils were made from

every observed fossiliferous bed, and subsequently these were studied in the Museum of Paleontology of the University of Michigan. These recent investigations showed that the strata referred by previous authors to the Tuxedni sandstone on the west shore of Cook Inlet include, at the base, beds which now are correlated with the Kialagvik formation of Lower Jurassic age. In the present paper the name "Tuxedni" is restricted to strata of Middle Jurassic age in conformity with the original definition.

The purpose of this paper is to describe some of the more significant guide fossils of the Tuxedni sandstone and to compare the Tuxedni sandstone section of the Iniskin-Chinitna Peninsula, which has been studied in some detail in the field, with the published type section of the formation on Tuxedni Bay. Evidence for several successive ammonite zones in the Tuxedni sandstone is presented.

Zones

4. *Miccocephalites* sp. A. cf. *M. concinnus*
3. *Oppelia chinitnaensis*
2. *Defonticeras stantoni*
1. *Zemistephanus moffiti*

By means of these zones the Tuxedni is correlated with all or part of the following formations: Fernie shale and Yakoun formation of Canada, Twin Creek limestone of southeastern Idaho, and the Ellis formation of Montana.

GEOLOGY AND PETROLEUM POSSIBILITIES OF THE NORTHERN PART OF THE INISKIN-CHINITNA PENINSULA

L. B. KELLUM AND H. WEDOW, JR.

University Museums, Ann Arbor, Michigan

Lower and Middle Jurassic rocks of the Tuxedni sandstone and Kialagvik formations comprise the surface rocks in the area mapped along the south side of Chinitna Bay. A deep test well should penetrate earlier Jurassic and Triassic strata. A section of the Triassic Kamishak formation over 3000 feet thick which crops out at Ursus Cove about 25 miles southwest of Chinitna Bay consists of interbedded quartzite and black limestone in the upper 1000 feet underlain by silicified gray limestone shot through with dikes and sills of gray-green, fine- to coarse-grained igneous rock. The Kialagvik formation now recognized for the first time on the Iniskin-Chinitna Peninsula has a thickness of over 2500 feet on the outcrop and consists of an upper coarse-grained unit about 900 feet thick of interbedded sandstones and conglomerates and a lower fine-grained unit about 1600 feet thick of shaly sandstone and sandy shale. The Tuxedni sandstone is a series of alternating shale and sandstone over 4000 feet thick. Both the Kialagvik and Tuxedni formations have yielded a large molluscan fauna.

The Fitz Creek anticline, situated in the southwestern part of the area covered by this report, is continued to the northeast by two diverging anticlines. These three and the Fitz Creek fault associated with them are the dominant structural features.

The writers believe that factors favorable to the presence of oil on the Iniskin-Chinitna Peninsula outweigh the unfavorable factors, and therefore further exploration is justified.

STRATIGRAPHY OF THE LOWER PALEOZOIC ROCKS SURROUNDING STISSING MOUNTAIN, DUTCHESS COUNTY, NEW YORK

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Stissing Mountain is upheld by pre-Cambrian gneisses, unconformably overlain by 250 feet of Lower Cambrian quartzite, succeeded by 2800 feet of dolomites and limestones of Lower Cambrian, Upper Cambrian, and Lower Ordovician age.

Over these early Paleozoic carbonate rocks is a series of phyllites interlayered with thin quartzite and limestone beds, in places conglomeratic. Heretofore these have been considered Lower Ordovician in normal position. Fossils have not yet been found in this pelitic series near Stissing Mountain, but lithic and structural evidence indicates that the pelites include rocks ranging from Lower Cambrian to Lower Ordovician, complexly folded and thrust over all the horizons of carbonate rocks that have been established by fossil evidence.

The stratigraphy of the carbonate sequence is given. Because of unsatisfactory exposures, thickness exceeding 50 feet at any one place can never be measured. Accordingly thickness ascribed to individual formations must be regarded as an estimate representing the relative order of magnitude with a possible error of several hundred feet.

LOWER ORDOVICIAN 750 feet

Rochdale limestone 400 feet

Limestones and dolomites carrying *Lecanospira* and orthoceratite cephalopods.

Halcyon Lake calc-dolomite* 350 feet

Rocks containing both calcite and dolomite. Carries *Ozarkispira*. Correlated with the Gasconade.

UPPER CAMBRIAN 2300 feet

Briarcliff dolomite* 1000 feet

Dominantly light dolomites with some dark beds. Carries new fossils *Prosaukia briarcliffensis* Lochman and *Plethemetopus knopfi* Lochman, a horizon not earlier than middle Franconian nor later than middle Trempealeauian stage, probably early Trempealeauian.

Pine Plains formation 1300 feet

Mainly dark impure dolomites. Lower beds carry cryptozoon reefs, some edgewise conglomerate, and oölite.

MIDDLE CAMBRIAN absent ?

LOWER CAMBRIAN 750 feet

Stissing dolomite 500 feet

Light-colored lower dolomites carrying *Hyolithellus micans* Billings in four localities. Upper dark dolomites carry *Paterina stissingensis* Dwight and *Prozacanthoides stissingensis* Dwight in two localities (one new). Indicates a late early Cambrian age.

Poughquag quartzite* 250 feet

Basal Cambrian, carrying *Olenellus* and probable *Obolella* near Beacon, New York.

The distinction between Lower and Upper Cambrian must be arbitrary because there is no structural unconformity to record middle Cambrian time. The top of the Lower Cambrian has been drawn above beds carrying *Paterina* as these fossils are now held to indicate upper Lower Cambrian. The overlying beds carry cryptozoon reefs, oölites, and edgewise conglomerates, an association characteristic of the Upper Cambrian.

STUDIES IN THE CORRELATION OF MINOR COAL BEDS OF THE McLEANSBORO GROUP USING FOSSIL SPORES†

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Among the thin coal beds of the McLeansboro group in Illinois and near the base of what is believed to be the equivalent of the Missouri series of Iowa is the thin coal bed of the Trivoli cyclothem outcropping in Peoria and Sangamon counties. As the stratigraphic sequence of the lower McLeansboro in Macoupin County is quite different from that in Sangamon and Peoria counties it is not

* Names not yet approved by Committee on Geologic Names of U. S. Geological Survey.

† Presented with the consent of M. M. Leighton, Chief, Illinois Geological Survey.

possible to correlate beds from Macoupin County to the other areas using lithologic criteria only. Since a coal bed a short distance below the Carlinville limestone in Macoupin County seemed to occupy about the same general position as the coal bed in the Trivoli cyclothem, which was designated coal No. 8 in Sangamon County by Worthen, fossil spores were used as a test of this possibility. Since the fossil spores characteristic of the Trivoli (No. 8) coal bed indicate a distinct break from the spores of the coal beds in the Des Moines series, the presence of spores of the Trivoli type in the Macoupin County coal bed would at least place it in the Missouri series, although it might not prove correlation with the Trivoli bed (No. 8). Actually, as the spores found in this coal are essentially identical with those characteristic of the Trivoli (No. 8) bed, the correlation of the coal in the three localities seems very probable.

VOLATILE TRANSFER IN EFFUSIVES AND INTRUSIVES

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The volatile transfer emphasized by T. M. Broderick seems, from analyses collected by him and from the chemists in the Rockefeller Laboratory in charge of Professor Grout and the Minnesota geologists to carry iron, copper, lead, and hydrogen up to escape in the effusives especially and not merely to accumulate at the top.

This is more marked in the coarser-grained flows and intrusions. Thus lead is lower in the flows than in the corresponding intrusives—for instance, the diabases intruded around Duluth, as compared with the flows of Keewenaw Point. The volatization may be thought of as a chloride compound, but water may divide into hydrogen and oxygen to make ferric compounds.

This promotes the formation of minerals like hematite and brown mica rather than magnetite and olivine, and this shows in the proportions of ferric and ferrous iron in the analyses.

There should be more of the primal lead and the more rapidly formed isotopes in the volatized lead than that produced by the decay of the radioactive elements. The rapidity of cooling is also a factor, giving more or less time for volatization.

GEOLOGICAL IMPLICATIONS OF THE LOESSES OF THE UPPER MISSISSIPPI RIVER VALLEY REGION

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This paper will deal with the vagaries in the geographic and stratigraphic distribution of the loess and their implications. The greatest areal development of the loess took place during the Wisconsin glacial stage in contrast to the scanty record of its deposition during the Nebraskan, Kansan, and Illinoian glacial stages. Furthermore, the loess of the Wisconsin glacial stage is related to various substages of valley trains of fine material in major valleys as sources of supply, except in the case of the Iowan glacial drift which was an important source. In reference to the Wisconsin loesses, the geological implications are, in the main, clear, but in the case of the scanty occurrence of loess belonging to the older glacial stages and in the instance of the so-called Late Sangamon loess, which in Illinois and Iowa is unconformable with the Illinois drift below and the Iowan or Peorian loess above, the inferences are singularly perplexing.

CLINOHUMITE AND ASSOCIATED MINERALS FROM DILLON, MONTANA*

MARIE LOUISE LINGBERG

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Clinohumite from Dillon, Montana, occurs as aggregates several centimeters thick of red anhedral grains in an enstatite rock associated with actinolite, anthophyllite, spinel, magnetite,

* Published with permission of the Director of the Geological Survey.

clinochlore, phlogopite, and forsterite. Its indices of refraction with sodium light are: $\alpha = 1.655$, $\beta = 1.678$, $\gamma = 1.700$. 2V is very close to 90°. The dispersion is strong. The pleochroism is X = orange, Y = pale orange, Z = yellow.

The earliest minerals to form are spinel, forsterite, and enstatite. Spinel is poikilitically enclosed in enstatite. Phlogophite, actinolite, and anthophyllite invade the forsterite and enstatite. Spinel is greatly attacked when actinolite was introduced. Clinohumite is one of the latest minerals to form and replaces forsterite almost completely. Excess iron from the formation of actinolite and clinohumite is found as magnetite. Clinochlore is associated with the clinohumite and magnetite.

BLEACHING OF RED SANDSTONES IN BELTS OF DEFORMATION

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In southern Nevada the Aztec sandstone, of Jurassic age, is 2000 to 3000 feet thick and extremely cross-bedded. Sand grains consist almost entirely of quartz, and a cement rich in ferric oxide gives the formation a brick-red color. In belts of severe deformation, and especially adjacent to major thrust faults, large masses of the sandstone, irregular in form and distribution, are variegated—yellow, gray, and white. Analyses show progressive decrease in content of iron and aluminum oxides with fading of the color. Some of the white masses are exploited as a source of high-grade glass sand. A thick formation of Cretaceous sandstone, the sand in which was derived from the underlying Aztec formation, has undergone similar bleaching effects.

Structural relations suggest strongly that the bleaching was accomplished by solutions which circulated along zones of faulting and crushing. Along the same sets of fractures, where they affect thick limestone formations, widespread dolomitization occurred, and ore minerals were deposited locally. Among the problems raised by these chemical effects, including the color changes in the sandstones, are the possible source and nature of the responsible solutions.

PEÑA BLANCA METEORITE, BREWSTER COUNTY, TEXAS

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The Peña Blanca meteorite fell August 2, 1946, in the swimming pool at the headquarters of the Gage Ranch near Marathon in Brewster County, Texas. Twenty-four people were within a few hundred feet of the point of fall, and one person saw the meteorite in flight.

Approximately 70 kg. (152 lbs.) of the meteorite was recovered consisting of one fragment of 47 kg. (104 lbs.), one fragment of 13 kg. (29 lbs.), and many smaller pieces down to mere grains. Reconstruction of the shape indicates that all but a few pounds of the stone have been recovered.

The meteorite is a white achondrite with a cream-colored crust and remarkable porphyritic texture. One phenocryst of pyroxene is 10 by 6 by 6 cm., another is 6 by 3 by 3 cm., and a number are larger than 3 by 3 by 3 cm. The groundmass shows considerable variation in grain size with abundant smaller grains 0.15 mm. in size.

Orthorhombic pyroxene is the principal constituent of the meteorite. Monoclinic pyroxene and olivine are of secondary importance. A very small amount of metal and suphide is present, and there is a trace of plagioclase feldspar.

GLACIAL WATER PLANES IN THE MOOSEHEAD LAKE BASIN, MAINE

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The north-south elongation of New England's largest lake and the position of its two outlets, approximately half way between its north and south ends, have influenced the history of its late-glacial and postglacial water levels. An early ice-dammed stage in the southern half of the basin

is suggested by eskers and glacial deltas; its outlet is over a divide toward the south. This high-water level would have been lowered when the present East Outlet was uncovered. Shore features in accord with this high level are lacking north of this outlet. When the ice front stood at Kineo the pitted outwash there was channeled down to and possibly below the present lake level.

Northward from Kineo and at a level lower than the earlier-mentioned water body, raised beaches, bars, and cut terraces rise in elevation, indicating a tilted water plane controlled at the present outlets. This lake level appears to have extended northward into the basin of Seboomook Lake. In the southern half of Moosehead Lake this same water plane must be tilted down below the present lake level by pivoting on the centrally placed outlets as the region has been uplifted toward the northwest. Recent raising of the lake for water storage has submerged the strong shores of colonial times, which are still visible from the air, and inaugurated a new era of shore construction. The extreme youth of the lake is attested by its double outlet.

ORIGIN OF THE COURSE OF THE MESSALONSKEE RIVER AT WATERVILLE, MAINE

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It has been assumed that when the rivers at Waterville, Maine, began to flow in postglacial time they first cut trenches in the lowest portions of the uplifted, drained clay floor of the late glacial ocean. This assumption does not explain the sharp turn which the Messalonskee makes when only half a mile from the Kennebec. Presence of fine deposits between the two rivers and absence of bedrock or buried glacial deposits at the turning point pose the question of why these rivers did not converge to make the shortest possible juncture at Waterville.

Sand-deposit remnants 10 feet or more thick overlying the clay in parts of Waterville between two rivers indicate a previously unrecognized interval of heavy sand deposition by the Kennebec River over a portion of the sea floor before the rivers channeled the clay beds. The westward slope of this deposit indicates that the sands so raised the flood plain of the early Kennebec that the Messalonskee, advancing its mouth as the sea receded, could not flow southeast through the present site of the city. Instead it turned, upon encountering the westward-spreading Kennebec sands, and flowed southwest for 2 miles along their western margin in a course like that of the Yazoo River to the Mississippi. Along its course the Messalonskee is now superimposed on bedrock above the entrenched and terraced Kennebec channel. Had the Messalonskee taken the shorter course through Waterville it would probably now occupy a recognized preglacial channel in the bedrock underlying the city.

IMPROVED METHOD OF COUNTING OUT PETROFABRIC DIAGRAMS

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In place of the conventional center and peripheral counters, a single sheet of millimeter graph paper is used on which a small number of suitably arranged 1 per-cent counting circles (1 cm. diameter) are drawn in ink. The point diagram is plotted on transparent cellulose acetate and provided with a tracing paper overlay upon which the contour diagram is drawn. Counting out involves successive 360-degree rotations of the superposed point diagram about a few appropriate centers marked on the grid. The counting circles and their centers are readily visible through the overlays and indicate the desired 1 per-cent counting areas for all positions of rotation. Percentage figures appear in circular arcs .5 cm. or .25 cm. apart, depending upon accuracy required, and concentric about the center of the diagram. Peripheral counts are made by utilizing opposing pairs of complementary circle segments drawn on the same grid. Similar provisions are made for azimuth counts.

This procedure is not only more rapid than the present method but also reduces fatigue resulting from constant shifting and centering of the conventional counters. Its particular advantage lies in greater accuracy of contouring, since continuous rotation of the point diagram permits determination of the critical loci of change in percentage figures.

EIGHTS' PIONEER OBSERVATION AND INTERPRETATION OF GLACIAL ERRATICS IN ANTARCTIC ICEBERGS

LAWRENCE MARTIN

Library of Congress, Washington, D. C.

Charles Darwin is credited with initial interpretation, in 1839, of glacial erratics in icebergs as indications of the size, position, and nature of bedrock of Antarctica. His basis was a single specimen collected by John Macnab, mate of the schooner ELIZA SCOTT in 61° S., 103° 40′ W., and information supplied by Enderby, Sorrell, Horsburgh, and Biscoe.

Nine years earlier James Eights of Albany, N. Y., anticipated Darwin in observation and interpretation of glacial erratics both ashore in the South Shetlands and in glacial icebergs studied at sea during a long voyage of exploration in the Pacific west of Palmer Peninsula and north of Ellsworth Land, Antarctica, to 70° S., 101° W., and thence northward. He was a geologist, zoologist, and meteorologist serving as ship's doctor on the brig SERAPH, one of three vessels under Captains Benjamin Pendleton and N. B. Palmer whose officers and crews carried on sealing, exploration, and scientific work between 1829 and 1831.

Present knowledge of Eights' observations and conclusions concerning Southern Hemisphere erratics is derived from previously unpublished logbook entries, memorials to Congress, and Eights' own publications. His conclusions were recognized abroad in his own time by Pierre Louis Antoine Cordier and Dumont d'Urville. John M. Clarke in 1916 and W. T. Calman in 1937 paid tribute to Eights without mentioning his contributions to glacial geology. James Hall characterized him as "the possessor of the keenest scientific mind that Albany had ever known."

Details of evidence concerning the 1830 observations and conclusions of Eights will be presented.

APPLICATION OF PETROGRAPHY TO ENGINEERING PROBLEMS

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Petrography contributes to engineering in numerous ways. Petrographic and related techniques facilitate selection of construction materials, such as: building stone, aggregates, earth and rock materials, cement clinker, and metals. Petrographic investigations are essential to fundamental research on concrete and will identify the causes of concrete deterioration. Petrographic classification and correlation of rock samples aid the field geologist in interpretation of subsurface conditions at construction sites. Petrographic methods may be used for forensic purposes to identify and describe materials subject to litigation. Microscopic and microchemical techniques lead to identification and analysis of extraneous substances formed within operating equipment, as well as paint pigments, cement admixtures, asphalt fillers, etc.

Petrography as applied to engineering must encompass chemical microscopy, metallography, X-ray diffraction, and phase-rule chemistry in addition to usual petrographic methods. Effective collaboration is required between petrographers and geologists, materials engineers, chemists, and research engineers. Co-ordination of research and integration of testing procedures have proved successful in the Petrographic Laboratory, a part of the Bureau of Reclamation laboratories at Denver.

In exploring new horizons, petrographers cannot be restricted by a narrow definition of the science. To be proficient, the petrographer must be experienced in physical and chemical methods for measuring properties of materials. His formal education should be broader than is normally provided by the curricula of most universities.

PETROLOGY OF CONCRETE AFFECTED BY CEMENT-AGGREGATE REACTION

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The permanence of concrete in engineering structures is jeopardized where high-alkali portland cement is used with aggregates containing opal, chalcedony, tridymite, intermediate to acidic vol-

canic rocks, or some phyllites. This type of deterioration, first recognized in 1938, is characterized by cracking, expansion, and decline in strength and elasticity of the concrete.

Petrographic and petrologic methods have contributed significantly to the investigation of cement-aggregate reaction. Microscopic criteria distinguish between this type of deterioration and other types. Petrographic examination of concrete aggregates can be used to predict their potential reactivity.

Physical-chemical conditions contributing to the deterioration were explored by petrologic and geochemical methods. The mechanism by which reaction between rocks and minerals and the alkalies of cement cause this destruction is explained. Essentially it consists of osmotic pressures produced by the formation and hydration of alkalic silica gels, which arise from interaction of alkalies and certain aggregates.

TRENTON PERRYVILLE FORMATION OF CENTRAL KENTUCKY

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The Perryville is present in outcrop in two areas in central Kentucky: (1) centering around Frankfort and Versailles, and (2) in the southern Bluegrass around Danville and Harrodsburg. In between the Perryville has not been recognized in the section.

It can now be shown that the Cornishville of the southern Bluegrass with its "recurrent" upper Benson fauna is, instead, the upper Benson. The Perryville is Benson, much of it a fine-grained and dove rock facies developing to the south.

However, the "Faulconer" and "Salvisa" constituting the "Perryville" of the Frankfort-Versailles area are post Woodburn. Inasmuch as the type area for the Perryville and for each of its divisions is in the Danville-Harrodsburg (southern) area, the post Woodburn "Perryville" is not Perryville, and other names must be assigned it and its subdivisions.

USE OF KODACHROME SLIDES IN TEACHING ELEMENTARY MINERALOGY AND LITHOLOGY

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During the past year the number of students taking elementary mineralogy and lithology at the University of Toronto has become so great that the author has found it impracticable to continue illustrating his lectures with actual specimens. Instead, a library of Kodachrome slides has been built up, and these are projected on the screen. This method has the advantage of placing before the students specimens of the finest quality on a scale where the details may be observed clearly by all simultaneously and without damage to the specimens.

APPLICATION OF BRIANCHON'S THEOREM TO CONSTRUCTION OF GEOLOGIC PROFILES

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Brianchon's theorem states that if a hexagon is circumscribed about a conic, the three diagonals will meet in a point. Any five nonparallel lines in a plane, such as five normals to the traces of parallel stratigraphic surfaces, will form a pentagon; and these five lines, if regarded as tangents, will define the shape and position of a conic. Brianchon's theorem is therefore modified to apply to a pentagon.

The conic that is thus defined is regarded as an evolute and is used to construct a set of involutes, which will represent the traces of parallel stratigraphic surfaces, in a profile normal to the strike of the

rocks. This construction affords a means of drawing profiles and measuring stratigraphic thickness, from five suitable structural observations.

This is a special case of the general method of evolute and involutes. It is offered, not as a substitute for the general method, but as a quicker means of obtaining similar results, where structural conditions justify its use.

PETROLOGIC RESEARCH ON REACTIVITY OF CONCRETE AGGREGATES

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Several common siliceous rocks and minerals react with alkalies released during hydration of portland cement and thereby effect deterioration of concrete. Wherever high-alkali cements are used in construction, potential deleteriousness of the aggregate should be determined. Reactivity may be established directly if the aggregate is combined with cement, or indirectly by methods not involving use of cement.

Direct methods include: (1) survey of concrete structures in which the aggregate was used; (2) laboratory testing of mortar and concrete containing the aggregate; and (3) the so-called "pat" tests. If data are complete, service records may be diagnostic. Tests of laboratory concrete and mortar are the best measure of deleteriousness of aggregate, but they are time-consuming. "Pat" tests, in which aggregate materials are embedded in neat cement, will detect only very reactive substances.

Indirect methods include: (1) petrographic examination, and (2) chemical tests. At present, petrographic examination is the only method capable of quickly evaluating reactivity of aggregates. Chemical instability is complexly related to deleteriousness of aggregates. Cation and hydroxyl absorption, dye absorption, simple dissolution by alkaline solutions, and etch of polished surfaces do not correlate with deleteriousness.

Recent petrologic research in the Bureau of Reclamation laboratories has developed a new chemical method by which deleteriousness is predicted from a relationship between the sum of dissolved silica plus undissolved, nascent silica produced from aggregates by a caustic solution and the reduction in alkalinity of the solution. The method is being adapted to a quick procedure for use in routine aggregate testing.

FUSED WOOD-ASH STONES: FAIRCHILDITE (n.sp.) $K_2CO_3 \cdot CaCO_3$, BUETSCHLIITE (n.sp.) $3K_2CO_3 \cdot 2CaCO_3 \cdot 6H_2O$, AND CALCITE, $CaCO_3$, THEIR ESSENTIAL COMPONENTS

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Stones found in the trunks of standing partially burned forest trees are produced by fusion and subsequent crystallization of the ash of the wood. Freshly formed stones consist essentially of fairchildite; on wetting, or by atmospheric hydration this is converted to buetschliite and calcite. On further leaching, the buetschliite is decomposed to calcite and water-soluble potassium carbonate. The presence of the first three carbonates in wood-ash stones is established, and a general account of these with a review of pertinent literature is given in this paper. The artificial compounds corresponding to fairchildite and buetschliite were prepared and analyzed by Otto Buetschli, in 1901–1905, but have not hitherto been found in nature. Fairchildite is hexagonal, $\epsilon = 1.48$, $\omega = 1.530$, and buetschliite is probably also hexagonal, with $\epsilon = 1.455$, $\omega = 1.595$.

THREE STAGES OF GLACIATION IDENTIFIED IN WIND RIVER VALLEY, WYOMING

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Glacial drift representing a stage of glaciation older than the Bull Lake and Pinedale moraines which were previously recognized by Miner and Delo (1943) in the DuNoir-Wind River area has been

identified 10 miles northwest of Dubois on the north slope of the Wind River Valley, Fremont County, Wyoming. The oldest drift is traceable for several miles along the valley slope southward from the junction of Long Creek Valley with the Wind River Valley. The third drift lies 75–100 feet above the previously identified Bull Lake moraine. It is older in appearance than the drift in the lower moraines and is composed chiefly of volcanics and does not contain limestone or sandstone boulders. The Wind River was apparently half a mile to a mile east of its present course in the vicinity of the locally called Stony Point, prior to the deposition of the older moraine, and was displaced by the morainic filling of its valley. The oldest drift is referred to the Buffalo stage on the basis of its weathering and topographic position.

NUEVITE, A NEW RARE-EARTH MINERAL FROM CALIFORNIA

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A heavy black mineral from the Southern Pacific Silica quarry near Nuevo, Riverside County, California, is shown to be a titano-niobate of yttrium and iron, with an additional fractional per cent of tantalum. Spectroscopic analysis shows no other rare elements, even in traces. The mineral thus appears to be a very simple member of the eschinite, samarskite, polycrase-euxenite group. It differs notably from any of the known species of this group and thus seems to be a new mineral, for which the name "nuevite" is proposed.

Its properties are as follows: crystals prismatic in habit, square or rectangular, with orthorhombic (?) symmetry. Color black, highly brilliant on fresh fracture. Nearly opaque, but transparent brown in very thin flakes. No cleavage. Fracture flat conchoidal. H 6.5, G 6.4. Optically isotropic, index 2.23. Fusible, yielding a little water in closed tube.

It occurs in grains and crude crystals in quartz, associated with a little cyrtolite and black tourmaline.

FAUNA FROM THE GREAT SMOKY MOUNTAINS NATIONAL PARK, TENNESSEE

ROBERT B. NEUMAN

A fauna from limestones exposed in Cades Cove, a fenster in the western part of the Great Smoky Mountains National Park, Tennessee, includes *Diaphelasma pennsylvanicum*, Ulrich and Cooper; *Finkelnburgia virginica*, Ulrich and Cooper; *Diparalasma* cf. *typicum*, Ulrich and Cooper; *Hystricurus* cf. *conicus*, Billings; gastropods related to *Lecanospira* and *Hormotoma*; and a cephalopod with *Orthoceras* affinities. The *Hystricurus* appears to be an undescribed species. Identifications are by Dr. G. Arthur Cooper. This fauna suggests a correlation with Longview and Odenville elements of the Beekmantown.

VARIETIES: WHAT IS THEIR FUNCTION IN PALEONTOLOGY?

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The variety, although part of the original Linnean scheme of classification, has pretty generally disappeared from modern classifications in neontology. It was always ambiguous, as it was applied to material of uncertain infrageneric rank. The majority of varietal names used by paleontologists were introduced for marginal members of normally variable populations. Some are based, however, on authentic species. The use of varietal names for these categories cannot be defended on biologic or stratigraphic grounds. Formal naming of varieties is not provided for in the International Code, nor is there any legal justification for the view that varieties and subspecies are taxonomically synonymous.

ZONES AND REPLACEMENT BODIES IN THE HUGO PEGMATITE, KEYSTONE, SOUTH DAKOTA

JAMES J. NORTON AND LINCOLN R. PAGE

The Hugo pegmatite, a mile south of Keystone, South Dakota, crops out as an irregular body about 580 feet long and 480 feet wide. It consists of two zoned segments separated in part by quartz-mica schist. The long axis of the outcrop trends northwest, but the individual segments strike east-northeast and dip north. Apparently the northern segment thickens, and the southern segment thins with depth.

Three types of structural units of pegmatite are recognized: zones, fracture fillings, and replacement bodies. The essential minerals of the zones from the pegmatite contact inward are: (1) oligoclase and quartz; (2) quartz, oligoclase-albite, and muscovite; (3) quartz, albite, and perthite; (4) quartz, cleavelandite, perthite (and microcline), and amblygonite; (5) quartz, microcline, and spodumene; (6) quartz and microcline; and (7) a core of cleavelandite, microcline, and lithia mica. Zone 3 is divided into three subzones on a basis of the proportion of perthite. The northern segment contains only zones 1 through 4.

Fracture fillings and replacement bodies of quartz-cleavelandite-perthite (and microcline), cleavelandite-quartz-lithia mica, and cleavelandite-quartz-microcline-lithia mica pegmatites cut all zones except the core. The largest replacement body is an offshoot of the core and crosses three zones that can be recognized by relict textures and minerals. Textures of the replacement bodies are distinguishable from the earlier replacement textures formed as the zones were first becoming consolidated.

Variations in composition of individual minerals and the abundance of replacement textures are correlated with the sequence of structural units.

RELATION OF PARAVAUXITE AND GORDONITE

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Paravauxite was described by Gordon as a triclinic mineral with the composition $FeO \cdot Al_2O_3 \cdot P_2O_5 \cdot 11H_2O$ (1922) or $FeO \cdot Al_2O_3 \cdot P_2O_5 \cdot 10H_2O$ (1944). Gordonite is the name given by Larsen and Shannon to the crystallographically similar mineral with the composition $MgO \cdot Al_2O_3 \cdot P_2O_5 \cdot 9H_2O$ (1930). Determinations of the unit cells of these two minerals, from sharp rotation and Weissenberg photographs, gave the following results in comparison with previous crystallographic data:

	a	*b*	*c*				
Paravauxite	5.23	10.52	6.955 kX	107°16½′	111°24′	72°29′	(1)
	0.4966	: 1 :	0.6609				
	0.4840	: 1 :	0.6882	107°32′	110°23′	72°09′	(2)
Gordonite	5.22	10.49	6.95 kX	107°29′	110°55½′	72°32½′	(3)
	0.4975	: 1 :	0.6628				
	5.25	10.49	6.97	107°20′	111°12′	72°12′	(4)
	0.5004	: 1 :	0.6644				
	0.5192	: 1 :	0.6942	109°27′	110°57½′	71°40½′	(5)

(1) E. W. N., X-ray. (2) Gordon, gon., preliminary values (1944), transformed. (3) E. W. N., X-ray. (4) Larsen III, X-ray (1942). (5) Pough, gon. (1937).

With $FeO \cdot Al_2O_3 \cdot P_2O_5 \cdot 9H_2O$ in the unit cell, *G* (calc.) for paravauxite is 2.375 compared to 2.358 (meas., Gordon), and this composition is also consistent with the recent analyses.

GEOLOGY OF ANDERSON RANCH DAM, BOISE RIVER, IDAHO

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Anderson Ranch Dam, now under construction on the South Fork of Boise River in southwestern Idaho, will be 444 feet high above bedrock on the canyon floor and will be the highest earth-fill dam in the world.

The geologic conditions of the site are important factors in the design and construction of the dam and appurtenant structures. The bedrock in the area is predominantly a granitic complex with a great range in quality, texture, mineral composition, and color. Many dikes, sills, and inclusions of various rock types occur in the granite; determination of their position, attitude, and physical condition is important from the engineering point of view. All the rock is severely jointed, and films of a fine claylike material occur in nearly all the joints; shear zones and faults are numerous. These geologic conditions, as well as the great depth of decayed rock in the left abutment of the dam, created many difficult engineering problems and materially influenced the design of the cut-off walls, outlet works and spillway. The character of the engineering geologic problems encountered during the course of the investigation and construction operations are discussed.

ELLIPSOIDAL STRUCTURES IN GLASS

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Some novel optical glasses made recently contain ellipsoidal structures similar in many respects to pillow-lava structures. The structures are shaped by convection currents in the liquid. The border of the ellipsoidal structures is schistose and commonly remains a glass even though the interior crystallizes. The difference in rate of crystallization of border and interior is a result of a difference in chemical composition and rate of cooling.

TWO SIMPLE TRANSFORMATIONS OF BRAVAIS SYMBOLS

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Simple transformation of Bravais symbols demands two zero points. Of the 144 possible simple transformations of Bravais' symbols from $a_1\ a_2\ a_3$ axes to a'_1, a'_2, a'_3 axes, referred to all possible zero points, with clockwise and counter clockwise succession of axes, there are 12 types, one of which is in simple accord with the transformation equation

$$\tan^2\rho - 3x^2\cdot c\,/3a^2 = y^2\cdot c^2/3a^2$$

where $$\tan^2\rho = \frac{4h^2 + 4hk + 4k^2}{1^2}\cdot\frac{c^2}{3a^2}$$

and $$x = h/1 \text{ or } k/1 \text{ or } (h+k)/1$$

and $$y = (h + 2k)/1 \text{ or } (2h + k)/1 \text{ or } (h - k)/1$$

This type transforms $(hk\bar{i}l)$ to $(\overline{[h + 2k]}\cdot[2h + k]\cdot\overline{[h - k]}\cdot 1)$ or $(\bar{h}'\bar{k}'\overline{k'}1)$.

Another type transforms $(hj\bar{i}l)$ to $(h'k'\bar{i}l)$. The other 10 types are only briefly discussed. All are in accord, graphically, with the transformation equation, but, in general, the assignment of the transformed indices to the proper axes requires reference to the gnomonic projection.

CONTACT METAMORPHIC MINERALS IN THE MELTING OF OPTICAL GLASS

WILLARD H. PARSONS AND HERBERT INSLEY

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Petrographic studies made at the National Bureau of Standards on the attack by various optical glasses on refractory clay pots revealed the presence of crystalline compounds analogous in composition and properties to several natural minerals. The description of the compounds found, together with data on the conditions and associations in which they were found, may give clues as to the source of the corresponding minerals. With barium glasses, celsian formed as bladed crystals at the pot-glass interface and also was abundant within the corroded refractory. Sanbornite was present sparingly with the celsian but was more commonly found as devitrification stones in the glass itself. Zinc spinel developed in the refractory as small, perfect octahedrons. Nephelite-kaliophillite and carnegieite solid solutions were present as reaction rims at the pot-glass interface. Mullite occurred abundantly in needles, corundum in thin, pleochroic plates, and cristobalite in skeletal crystals.

The formation of corundum by the action of a melt containing silica and alkalies on an aluminum silicate wall material is explained by the phase relationships in the system Na_2O-Al_2O3-SiO_2 and may be similar to the origin of corundum at the contact of syenite with aluminum silicate country rock. The presence of celsian and sanbornite in the refractory may also parallel natural occurrences in contact zones. Nephelite and carnegieite solid solutions occur together only at high temperatures under known equilibrium conditions. The formation of zinc spinel by glasses with only 3 per cent of zinc is in accordance with the large field of zinc aluminate in the system SiO_2-ZnO-Al_2O_3.

INDEXED X-RAY POWDER SPECTRA OF THE ORE MINERALS

M. A. PEACOCK

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A satisfactory standard x-ray powder spectrum consists of good reproductions of powder films made on authentic natural and, if possible, artificial material with Cu/Ni or Fe/Mn radiation, accompanied by a table giving the unit-cell constants (corrected if necessary), the observed intensity of each powder ring on a scale of 10, the measured glancing angle, the measured interplanar spacing, the indices (*hkl*) of the reflecting planes, and the calculated spacing. A full set of such spectra is being prepared in Toronto to supplement existing röntgenographic data for the identification of the ore minerals.

NEW CHARTS FOR TEACHING CRYSTALLOGRAPHY

TERENCE T. QUIRKE

University of Illinois, Urbana, Illinois

Charts have been prepared on the basis of Maugin's system as used in the International Tables. One chart is drawn to illustrate forms characteristic of the 32 classes, indicating the elements of symmetry for each class. Another chart lists, in parallel rows, names of classes according to three representative nomenclatures, the number of faces in the form, the elements of symmetry, the symmetry notations, with the addition of the space-lattice groups pertaining to each crystal class and point group. These charts make a very convenient reference and have proved to be a great aid in teaching crystallography.

TEACHING OF ENGINEERING GEOLOGY

TERENCE T. QUIRKE

University of Illinois, Urbana, Illinois

The teaching of engineering geology must be either engineering or geology. Experience indicates the wisdom of making such a course a course in geology. The last 25 years have seen a very large increase in interest in geology by nearly all engineers, especially civil and military engineers, in addi-

tion to the usual demands from mining engineers and those engaged in mineral explorations. There is a definite demand for technical data of all geological types: soil mechanics, requiring analysis of physical properties; ceramic and industrial engineering involving the nonmetals, requiring detailed mineralogical instruction; a better demonstration of the usefulness of structural geology; the nature and distribution of ground water; flood control, and conservation of soil by control of erosion; river and harbor maintenance, shore protection, and the effects of tides; an enlarged appreciation of the seaways and inland highways for transportation; an appreciation of types of topographies and drainage systems. All these topics demand to be covered in most engineering curricula within a single course in Geology. There is not time enough to teach the topics commonly covered in elementary geology; severe reorganization of materials, with drastic cutting of cherished and traditional subject matter, must be effected. To give the most useful geology possible in the shortest time is the crux of the problem. To decide what geology is most useful requires close heed to the trend of the times in various branches of engineering.

PREPARATION OF RUTILE TITANIUM DIOXIDE

TERENCE T. QUIRKE AND ROBERT STEINMAN

University of Illinois, Urbana, Illinois

Rutile occurs in nature in low-temperature quartz but seems not to be stable synthetically below 1040°C. By heating anatase intimately ground with another compound of the rutile lattice structure to 900°C for 2 hours part conversion to rutile was achieved within the brookite range. However, with the addition of SiO_2 almost perfect conversion to rutile was accomplished in nearly every case. Germanium dioxide was also found to be efficacious.

The use of silica to coerce the formation of the rutile structure differs from the common use of seed crystals in that it involves the mutual packing effects of lattices which are not isomorphous. In this respect the procedure is thought to be unique.

COMPOSITION AND UNIT CELL OF HYDROZINCITE

LEWIS S. RAMSDELL

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Specimens of hydrozincite from Goodsprings, Nevada, show tiny crystals projecting from fine-grained massive material. The crystals are bladelike and taper to a sharp point. They are up to 2 mm. in length, slender, and very thin. The only well-developed form is the pinacoid (100). Edge faces give very indistinct reflections on the goniometer, and no measurable terminal faces were observed. Weissenberg photographs confirm the previous assignment to the monoclinic system. The space group is either $C_2/_m$, C_m, or C_2, the characteristic missing hkl reflections being those with $h+k$ odd. Unit-cell dimensions, derived from 0-level, b- and c-axis rotations, are: $a = 13.452kX$, $b = 6.307$, $c = 5.357$; $\beta = 95°30'$ (x-ray). The volume of the unit cell, together with the values of d given in the literature, 3.6–3.8, do not give any simple proportions of $Zn(CO_3)$ and $Zn(OH)_2$. Tests in Clerici solution indicate a d close to 4.0, and this agrees well with a unit-cell composition of $4Zn(CO_3)\cdot 6Zn(OH)_2$.

Crystals of aurichalcite from the Magdalena district, New Mexico, closely resemble those of hydrozincite, except for their pale-green color. However, Weissenberg photographs indicate that, although closely related, aurichalcite is not isomorphous with hydrozincite.

PROBLEMS OF TRAFFICABILITY*

LOUIS L. RAY

U. S. Geological Survey, Washington, D. C.

In modern warfare motorized equipment must be quickly and effectively moved across terrain, requiring appraisal of trafficability conditions for areas often inaccessible to field study. Appraisal

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involves integration of variable, complex, and closely interrelated factors, many relatively unknown and unsolved. Wartime appraisal was qualitatively derived from available terrain information and correlation with analogous areas of known trafficability conditions. Peace time provides opportunities for fundamental field and laboratory studies of trafficability factors, the understanding of which is important in a peacetime economy.

Trafficability factors are grouped into five major categories, each affecting and dependent on the others. By analysis of each and correlation with the others the trafficability situation can be determined.

(1) *Vehicle performance.* Each type of vehicle reacts differently to different physical terrain conditions. To understand and appraise their movement, quantitative studies of the mechanics of that movement relative to ground conditions are essential.

(2) *Topography.* Character of slopes and water features are the basis for terrain appraisal; they must be analyzed relative to vehicle performance.

(3) *Soil conditions.* Physical character of soil profiles under various climatic and weather conditions must be correlated with performance of vehicle types.

(4) *Climate and weather.* Differences between hot or cold and wet or dry conditions are reflected not only in the character of terrain and soil, but in vehicle performance. Detailed analyses of expectable climate and weather must be ascertained so that appraisal may cover all conditions.

(5) *Vegetation and land use.* Modifications of virgin soil by agricultural usage changes its properties. Plant cover directly affects trafficability and modifies soil and soil-drying rates.

DEGLACIATION IN THE RONDANE AREA, NORWAY*

LOUIS L. RAY AND ARTHUR C. TROWBRIDGE

U. S. Geological Survey; State University of Iowa

Rondane, a "fretted" mountain group approximately 200 miles northeast of Bergen, rises to a height of 7200 feet. It is believed to have been completely buried beneath the last great Scandanavian ice sheet.

Field observations in the summer of 1946, during the Rondane international field conference, indicate that deglaciation took place by the melting of stagnant ice *in situ*. With amelioration of climate and consequent cessation of accumulation, the ice covering Rondane became climatically dead. Movement ceased and downwasting through melting and ablation uncovered first the higher mountain peaks. Cirques and hanging cirque valleys became ice-free, while major valleys were occupied by slowly melting stagnant ice. Deglaciation was completed with the melting of the protected ice in the major valleys.

This concept is based primarily on six lines of evidence: (1) lack of recessional moraines, (2) series of parallel ice-margin drainage channels on valley walls, (3) "consequent" eskers trending normal to valley axes on sloping valley walls, (4) abandoned spillways across cols, to some of which are related wave-cut shore lines of ice-dammed lakes, (5) ice-contact fluvio-glacial deposits in major valleys, and (6) areas of crevasse filling, ablation, and kettle moraines on valley bottoms and divides.

Lateral drainage channels pass without interruption across slopes below hanging cirque-headed valleys, indicating abandonment of cirques while major valleys were occupied by wasting ice.

TIP TOP SAND AND THE MERAMEC-CHESTER UNCONFORMITY IN KENTUCKY*

LOUIS L. RAY, ARTHUR P. BUTLER, JR., AND CHARLES S. DENNY

U. S. Geological Survey

In Hardin and Meade counties, Kentucky, on the Pennyroyal Plateau near Tip Top, a deposit of poorly consolidated sandstone, called the Tip Top sand, has been quarried for glass and molding

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sand. At this type locality, about 50 feet of sandstone rests unconformably on the Mississippian St. Louis limestone. Previous descriptions have assigned to the Tip Top sand a variety of origins and age interpretations ranging from Mississippian to Tertiary.

Recent field mapping shows that the sandstone at the Tip Top quarries lies near the northeast end of a well-defined ridge of sandstone. This ridge can be traced across the bevelled Mississippian St. Louis and Ste. Genevieve limestones of the plateau for about 11 miles to the southwest, where the sandstone merges with the lowest sandstone of the Chester group, tentatively referred to the Mooretown sandstone as described by Malott and Stouder. Numerous isolated and poorly exposed outcrops of similar sand and sandstone are scattered across the somewhat dissected limestone plateau in the area southeast of the ridge. At no place was the base of the sandstone observed along the ridge or in the isolated outcrops. However, the sandstone of the Chester group with which it merges rests unconformably on a limestone surface which has a maximum observed relief of approximately 100 feet in half a mile.

It is suggested that in this area the unconformity at the base of the sandstone be considered the break between the Meramec and Chester groups of the Mississippian series and that the term Tip Top sand be abandoned.

FOUR PALEOZOIC HABITAT GROUPS

IRVING G. REIMANN

Williamsville, New York

Middle Silurian (Rochester), Upper Silurian (Bertie), Middle Devonian (Onondaga), and Upper Devonian ("Chemung") faunas are restored in four 14-foot habitat groups recently installed at the Rochester, N. Y., Museum of Arts and Sciences. Vivid colors, similar to those of their living relatives, were liberally used in restoring the organisms. Many new restorations of various invertebrates are included. All of the restorations and backgrounds were executed by George Marchand.

ORGANIZATION AND FUNCTIONS OF THE GEOLOGY SECTION, BUREAU OF RECLAMATION

ROGER RHOADES

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The main function of the Bureau of Reclamation is to conserve and deliver water for the irrigation of the semiarid areas of western United States. The responsibility of the Bureau's geologists is to secure the geologic data needed by the engineers in providing the required dams, tunnels, canals, pumping plants, and powerhouses.

The geologic operations are organized to insure: (1) investigations directed toward solution of specific engineering geologic problems presented by these structures; (2) simultaneous servicing of numerous active investigations scattered over a large geographical area; (3) co-ordination of daily operations of geologists and engineers in order that geologic studies may be guided continuously by engineering objectives and engineering decisions based on complete geologic information. Field, office, and laboratory aspects are co-ordinated to serve different engineering viewpoints in successive stages of (1) preliminary investigation and planning, (2) final design and construction, and (3) operation and maintenance.

The central Geologic Section consists of: (1) nuclear group of engineering geologists, materials engineers, and specialists in ground-water geology, geophysics, and photogrammetry; (2) Petrographic Laboratory for applied petrography, geochemistry, and microscopy; (3) Earth Materials Laboratory for application of soils-mechanics principles to earth materials. The Section was established within the Division of Engineering and Geological Control and Research to facilitate co-operation with other technical Sections of that Division engaged in basic structural research, hydraulics, engineering chemistry, concrete materials, and basic research in soil mechanics. A Regional Geologist and staff

are maintained in each of seven strategically located western cities in addition to resident geologists at district offices and specific major projects.

URANINITE AND PITCHBLENDE

AUSTIN F. ROGERS

Stanford University, Calif.

It is proposed to use the name uraninite for the crystalline (isometric), essentially uranium dioxid (UO_2) mineral, with specific gravity varying from about 8.0 up to about 10.5 and low water content, and the name pitchblende for its massive or colloform amorphous equivalent (mineraloid) with a specific gravity varying from about 6.8 up to about 8.5 and a water content varying from about 2 per cent up to 5 per cent.

URANINITE CRYSTALS WITH A NEW FORM FROM PORTLAND, CONNECTICUT

AUSTIN F. ROGERS

Stanford University, Calif.

Euhedral crystals of uraninite from one of the pegmatites at this locality are octahedra modified by the cube, the dodecahedron, and a new form, the tetrahexahedron $\{520\}$. The latter is determined on a matrix specimen by measurement on the microscope stage of the plane angle formed on the (520) face by its intersections with (111) and $(11\bar{1})$, which may be expressed as the interzonal angle $[2\bar{5}3] \wedge [\bar{2}53]$.

The uraninite crystals occur on a matrix of feldspar which proves, on optical examination, to be albite with the approximate composition $Ab_{95}An_5$. The albite is a replacement of microcline, which is present in very small amounts as a relict mineral.

Besides the usual cleavages parallel to $\{001\}$ and $\{010\}$ the albite shows fair cleavage parallel to $\{110\}$, and both albite and pericline twin-lamellae, as well as pericline parting.

CLASTIC DIKES OF THE PIKES PEAK REGION

CHALMER J. ROY

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Dikes composed typically of fine- to medium-grained sandstone but locally containing coarse rounded or angular material have been injected into the pre-Cambrian rocks of the Pikes Peak region. These dikes occur in a narrow belt approximately 50 miles long and generally less than a mile wide.

The dikes range in width from a fraction of an inch to more than 300 feet and in length from a few feet to more than 3 miles. Structurally the dikes vary from simple through multiple and composite injections to highly complex masses. Except for composition they are analogous in every respect to igneous dikes.

The dikes are closely associated with known thrust faults, occurring in the crystalline rocks of the upthrown block at or near the outcrop of the fault plane. Individual dikes strike essentially parallel to the trend of the associated fault and dip in the same direction as the fault but more steeply.

It is believed that these dikes were formed by the injection of quicksand-like material into fractures in the crystalline rocks of the upthrown block during faulting, and that the materials of the dikes were derived mainly from sedimentary rocks of the downthrown block.

ELECTRONICS AND SUBMARINE GEOLOGY*

R. DANA RUSSELL

U. S. Navy Electronics Laboratory, San Diego 52, California

Wartime research on the transmission of underwater sound in shallow water, together with the development of special sonar devices, promises great improvements in the rapidity and accuracy of submarine geological surveys.

Scattering and absorbtion coefficients of the bottom depend on bottom type; over certain types of sediments, the bottom-reflection loss can indicate even the grain size of the bottom sediment. It is now possible, therefore, to develop an instrument which will record changes in bottom character from a ship underway.

A device which presents a visual profile of the bottom would also be useful in survey work. Such a device has been developed and is now being perfected at the Navy Electronics Laboratory.

GEOLOGISTS AND SONAR†

R. DANA RUSSELL

University of California Division of War Research, San Diego, California

Sonar, the underwater counterpart of radar, played a decisive role in the Battle of the Atlantic, contributed to the success of our submarine warfare in the Pacific, and aided in the defense of our harbors and advanced bases.

The effectiveness of sonar devices depends, to a large extent, upon oceanographic conditions—the sea surface, temperature and salinity gradients, and, in shallow water, upon the character of the bottom. Geologists proved particularly adaptable to sonar research and played an important part in the Navy's effective use of sonar devices. At Navy and NDRC war research centers, they participated in fundamental research on the behavior of underwater sound, in harbor-defense surveys, in the preparation of charts for the Fleet, and in the training of Navy personnel in the most effective use of sonar equipment under various types of water conditions. The present Fleet doctrine for antisubmarine warfare has partly resulted from the studies of a group in which geologists and oceanographers were major contributors.

PRELIMINARY DATA ON IRON-BEARING MELILITES IN THE QUATERNARY SYSTEM CaO—FeO—MgO—SiO_2

J. F. SCHAIRER AND E. F. OSBORN

Geophysical Laboratory, Washington, D. C.

A few compositions have been studied in a small portion of the join $CaSiO_3$—MgO—FeO in the quaternary system CaO—FeO—MgO—SiO_2. Compositions between akermanite ($Ca_2MgSi_2O_7$) and its iron analogue ($Ca_2FeSi_2O_7$) and between monticellite ($CaMgSiO_4$) and its iron analogue ($CaFeSiO_4$) lie in this join. The phase relations for the join have been roughly outlined, and the optical properties of the melilites have been determined. There is a continuous series of melilites between akermanite (optically uniaxial and positive) and its iron analogue (optically uniaxial and negative). The intermediate member containing approximately 72 weight per cent of akermanite is isotropic for sodium light.

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* This paper is based upon research carried out by the University of California Division of War Research under contract NObs-2074 with the Bureau of Ships, Navy Department, and by the U. S. Navy Electronics Laboratory.

† This work represents one of the results of research carried out by the University of California Division of War Research under contracts with the Office of Scientific Research and Development, Section 6.1; National Defense Research Committee; and with the Bureau of Ships, Navy Department.

SUBMARINE TOPOGRAPHY OFF ELEUTHERA ISLAND, BAHAMAS

MARSHALL SCHALK

Smith College, Northampton, Massachusetts

Details of a bottom chart of the area immediately off the Atlantic Coast of Eleuthera Island, Bahamas, are presented. Data were obtained in the course of work under a Bureau of Ships, U. S. Navy, contract with the Woods Hole Oceanographic Institution. The extremely irregular seaward slope is further illustrated by a series of profiles, each based on a single line of echo soundings, drawn without vertical exaggeration. Slopes exceeding 30° are common. On certain profiles slopes exceeding 45° are indicated by three or more soundings. Of particular interest is the sharp drop or "cliff" always found between 30 and 100 fathoms. The general location of the area as well as its relation to the Bahama Bank is given by a small-scale chart contoured at an interval of 500 fathoms.

APPLICATION OF X-RAYS TO PALEONTOLOGY*

RUTH A. M. SCHMIDT

U. S. Geological Survey, Washington, D. C.

X-ray photographs, or roentgenograms, of a fossil specimen can be made that will reveal the internal structures without harming the specimen, or will precisely locate the position of the specimen if it is enclosed in matrix. The most recent and extensive work in this field has been done in Germany prior to World War II. Dr. W. M. Lehmann, a member of the medical faculty at Hamburg, worked with Rudolf and Emily Richter on specimens from the Hunsruckschiefer, of lower Devonian age. The specimens included silicified crinoids, arthropods, and cephalopods. The purpose of the present study is not only to see what results can be obtained with all types of fossil preservation, but to apply that knowledge to a systematic study of each phylum.

OSTRACODS FROM THE UPPER CRETACEOUS AND EOCENE OF MARYLAND, DELAWARE, AND VIRGINIA*

RUTH A. M. SCHMIDT

U. S. Geological Survey, Washington, D. C.

The ostracod faunas from the Upper Cretaceous beds of Maryland and Delaware, and the lower Eocene beds of Virginia and Maryland are described. Samples were collected from typical outcrops of the Marshalltown formation of the Matawan group, the Monmouth group, both Upper Cretaceous, and from the Aquia formation of the Eocene. Additional samples were collected along the strike of the outcrops in Maryland. Tentative correlations are made with the Marshalltown and Mount Laurel formations in New Jersey. Species previously described are discussed, and new species are described and illustrated.

HYDROTHERMAL ALTERATION IN THE "PORPHYRY COPPER" DEPOSITS†

GEORGE M. SCHWARTZ

University of Minnesota, Minneapolis, Minn.

The hydrothermal alteration which was accompanied by the introduction of copper sulfides in the disseminated copper deposits is considerably more complex than is generally recognized.

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Detailed microscopic study of selected porphyry specimens from the important producing deposits in the United States, together with a review of published data, leads to the recognition of four main types of alteration which may be characterized as follows:

1. Quartz-orthoclase.—Alteration to and/or introduction of quartz and orthoclase with a fairly favorable ratio of chalcopyrite to pyrite. Ajo, Ely, Bagdad, Utah Copper (in part).
2. Quartz-sericite-pyrite. Inspiration-Miami, Ray, Sacramento Hill, Castle Dome (in part), Utah Copper (in part).
3. Sericitic and argillic alteration with quartz subordinate. Morenci, Chino, Castle Dome (in part), San Manuel.
4. Biotitic alteration. Utah Copper (in part) and Ely (in part).

No district is a simple example of one kind of alteration but shows a dominance of one or two types. Most districts show a rather long list of alteration products when studied in detail.

The argillic alteration has been little emphasized in earlier work but is very important in several districts, of which Morenci is an outstanding example. The clay minerals are found in the sulfide ore and are characteristically earlier than sericite.

The more important clay minerals include: hydromuscovite, kaolinite, allophane, halloysite and beidellite. Less common are: potash clay, montmorillonite, and dickite.

Available chemical data indicate that calcium and sodium are usually removed from the rock to a significant degree, and potassium remains constant or increases. Silica is gained in a few deposits but usually shows minor changes. Quartz, no doubt, is often formed by the freeing of silica during alteration.

SUBMARINE CANYONS AND WAR RESEARCH*

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Investigations conducted by the University of California Division of War Research, at Point Loma, and the Scripps Institution during and to some extent following the war provided new information bearing on the nature and origin of submarine canyons. Improved contouring of Coronado Canyon southwest of San Diego and of Todos Santos Canyon along the Lower California coast was made possible by extensive soundings. The apparent filling of the head of Todos Santos Canyon was indicated by the contours and the nature of the bottom sediments. The wave and beach studies at Scripps Institution showed the significant effect of submarine canyons on wave height and longshore currents in their vicinity. A reason for the failure of the canyon heads to become filled is suggested by this study. The construction of bottom sediment charts along the Asiatic coast has also shown some of the wave and current effects. The rocky walls of the canyons around Japan and Formosa were indicated on the detailed charts used in the construction of the bottom sediment compilations.

BOTTOM-SEDIMENTS CHARTS OF THE ASIATIC CONTINENTAL SHELVES†

F. P. SHEPARD AND K. O. EMERY

Scripps Institution, La Jolla; Univ. of Southern Calif., Los Angeles

During the war charts were prepared for the U. S. Navy showing the bottom character on the continental shelves along the eastern and southeastern coasts of Asia. These charts were published by the Navy Hydrographic Office, and copies will be placed on exhibit during the meetings of

* This work represents one of the results of research carried out by the University of California Division of War Research under contracts with the Office of Scientific Research and Development National Defense Research Committee Section 6.1, and with the Bureau of Ships, Navy Department.

† This work represents one of the results of research carried out for the National Defense Research Committee and the Bureau of Ships, Navy Department, by the University of California, Division of War Research.

the Geological Society. The charts are based on bottom notations from the most detailed Japanese, British, Dutch, and French charts which were available in the files of the Hydrographic Office. A total of about 300,000 notations were used.

The charts show that sediment is distributed irregularly over the Asiatic continental shelves. In few places is there a gradation outward from coarse sediment to fine. Along much of the east Asiatic coast mud predominates on the inner shelf, and sand outside. Large rock areas occur particularly along the Japanese coast where the Kuroshio is flowing at a high speed. Rock notations are abundant on submerged hills, off rocky points, in narrow straits, and at the outer edge of the shelves. Mud is found in enclosed bays, and sand is most common in broad open bays although mud is present in the latter off some large rivers. Sand is the most common type of sediment reported from the Asiatic shelf, although it does not predominate as much over mud as is the case on most other shelves of the world. Similar charts were constructed for Atlantic areas by Henry C. Stetson and his associates of the Woods Hole Oceanographic Institution.

RECENT TSUNAMI IN THE HAWAIIAN ISLANDS

F. P. SHEPARD, G. A. MACDONALD, AND D. C. COX

La Jolla, Calif.; Honolulu, T. H.

A series of waves coming from the Aleutian trench hit the shores of the Hawaiian Islands on the morning of April 1, 1946. These waves were witnessed by Shepard; the house in which he was living was largely destroyed by them. A joint investigation of wave damage to the five main islands was conducted by the writers. High-water marks were established around the shore lines of the islands, and the attempt was made to correlate cause and effect with the hope that danger spots in future waves could be predicted. The waves were extremely variable in their effect. In one locality an increase from 7 to 54 feet was found in 5 miles; the entire area was exposed to the direct approach of the waves. The investigation indicated the following:

1. Long submarine ridges facing the wave approach cause convergence and high waves
2. Submarine valleys facing the wave approach dampen the waves by wave divergence
3. Coral reefs greatly decrease the wave height
4. Peninsulas terminated by steep submarine slopes have low wave heights
5. Waves funnel and rise at the heads of some estuaries depending on their shape
6. The waves bend around islands of circular shape with less loss of height than around elongate islands

BEATRICIDAE

W. H. SCHIDELER

Evidence is presented showing that *Aulacera*, *Beatricea*, *Cryptophragmus*, and *Thamnobeatrices* are fundamentally a single type of organism which has been overgrown by various types of *Solenopora*, *Labechia*, *Stromatocerium*, etc. The central camerate tube is possibly an alga, and probable fruiting bodies are indicated.

GENUS *Cyclocystoides*

W. H. SCHIDELER

The genus consists of a supporting circle of plates, to which articulates an aboral wall of minute multiradiate plates, and also an oral wall that is probably hemispheric. These relationships are shown and discussed.

CLASSIFICATION OF SEDIMENTARY ROCKS

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Massachusetts Institute of Technology, Cambridge, Mass.

A proposed field classification of sedimentary rocks has two divisions—fragmental and precipitated. New terms are proposed for individual rock types and groups of rocks which thus far have received ambiguous or confusing names. *Sharpstone* conglomerate is suggested for cemented deposits of coarse angular fragments (*sharpstones*) or rubble. Sedimentary breccias are included in this category. Roundstone conglomerate is suggested for cemented deposits of roundstones or gravel. *Silicastone* is proposed for rocks composed dominantly of silica and includes radiolarian and diatomaceous rocks on the one hand and chert, flint, etc., on the other. It is suggested that the practice of using mineral names for rock designations be abandoned and that the following new rock terms be adopted: *dolostone* for rocks heretofore called dolomite and *salinastone* for the common saline rocks heretofore called gypsum and anhydrite. Gyprock and *anhydrock* merit consideration as designations for the two common salinastones just mentioned. The other terms of the classification have been in use long enough to have become established in petrological literature. Fragmental sedimentary rocks include sharpstone and roundstone conglomerates; sandstone; siltstone, claystone and mudstone; shale; limestone (fragmental type); silicastone (fragmental type); and coal. Precipitated sedimentary rocks include limestone (rare), dolostone, salinastone (gyprock and anhydrock), silicastone, and ironstone.

STRATIGRAPHIC POSITION OF THE SHOAL CREEK AND CARLINVILLE LIMESTONES IN SOUTHWESTERN ILLINOIS*

JACK A. SIMON AND GILBERT H. CADY

Illinois State Geological Survey, Urbana, Illinois

A study of the Shoal Creek and Carlinville limestones in their type areas in Clinton and Macoupin counties shows that these two limestones, which for some years have been regarded as the same, actually lie at different stratigraphic positions.

Halysites quebecensis LAMBE

G. WINSTON SINCLAIR

This species, from the Black River of the Lake St. John area, is of particular importance as the oldest member of the genus. Its development and morphology are described in detail.

AERIAL PHOTOS IN GEOLOGIC TRAINING

H. T. U. SMITH

University of Kansas, Lawrence, Kansas

In training geologists, the use of aerial photos provides a means of presenting many phases of the science with maximum effectiveness and introduces modernized techniques in geologic mapping and research. For the study of landforms, structures, and stratigraphic relations, at both elementary and advanced levels, photos offer a direct and realistic approach otherwise difficult to attain. Judicious selections from the large volume of photography now available for much of North America, and for many areas on other continents, in effect bring world-wide field data into the laboratory for deliberate examination.

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* Published with the permission of M. M. Leighton, Chief, Illinois Geological Survey.

Photogrammetric techniques are now being used to a rapidly increasing extent in geologic mapping, and photo-interpretation has already made possible important advances in geologic knowledge. Training in these fields has come to be of basic value to the geologist and constitutes an important requisite for further advances in the science itself.

DRAINAGE EVOLUTION IN THE CENTRAL HIGH PLAINS

H. T. U. SMITH

University of Kansas, Lawrence, Kansas

Existing stream courses in the central High Plains are interpreted as of late Tertiary or Early Quaternary age. Differential upwarping of the Pliocene depositional surface channelized the flow of older streams issuing from the mountains and gave rise to a new set of streams arising within the plains, and consequent on the upwarped surface. These streams formed a semiradial pattern, indicating a broad, fan-shaped uplift with its apex on the Platte-Arkansas Divide, near the mountain front. During Quaternary time, the stream pattern was modified by piracy and by local subsidence.

GEOLOGY OF THE RED ROSE TUNGSTEN MINE, HAZELTON, BRITISH COLUMBIA*

JOHN S. STEVENSON

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The Red Rose mine was British Columbia's largest producer of tungsten during World War II.

Scheelite occurs in a shear zone that cuts Mesozoic Coast Range intrusives and hornfelsed tuffs within 750 feet of the Rocher Déboulé batholith.

The minerals include scheelite, some ferberite, and, in order of abundance: quartz, orthoclase, albite, apatite, biotite, hornblende, chalcopyrite, and molybdenite. Cobaltian arsenopyrite, pyrrhotite, chalcopyrite, quartz, and tourmaline occur in the shear beyond the scheelite.

Spectrographic analyses of 30 specimens of wall and near-by rocks and of specimens of vein and rock minerals showed variations of the trace elements in groups in which the range in atomic radii was within the 15 per cent limit allowed by Goldschmitt in his rule for isomorphism of elements. Tungsten was absent in all the rock analyses; apparently it did not wander as a trace element into the wall rocks.

The scheelite ore occurs in two shoots where the shear cuts a 400-foot diorite sill but is not found where the shear cuts hornfelsed tuffs. The stress diagram of the vein shear and related breaks shows that the two ore shoots pitch in the same direction as the pitch of the intersection of potential tension openings within the vein.

The lenticular form, coarse to pegmatitic texture, and mineralogy of the tungsten vein imply formation at high pressure and temperature (the hypothermal class of veins). As a producing property, the Red Rose is unique in a class of scheelite deposits that does not ordinarily include commercial deposits of tungsten.

PUMICE FROM HAYLMORE, BRIDGE RIVER, BRITISH COLUMBIA

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Pumice of Recent age from Haylmore's placer mine, Bridge River district, British Columbia, is highly vesicular and also shows pronounced fluidal structure. The pumice is vitrophyric; the volcanic glass of the groundmass has a refractive index of 1.497. The principal phenocrysts are plagio-

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clase feldspars (Ab_{70} An_{30}) characterized by an abundance of glass inclusions. Glistening black hornblende phenocrysts are also found. A chemical analysis of the pumice and results of X-ray studies are given.

HYPOTHESIS FOR CONTINENTAL GLACIATION

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The effects on world climate of large land masses and the difference in climate between the northern and southern hemispheres are the basis for a proposed hypothesis that major earth deformation is the primary cause of regional glaciation. The basic concepts include the development of anticyclonic circulation in certain favored positions over large cool land masses, the migration of such anticyclonic centers toward winds bearing moisture, and the consequent displacement of cyclonic storm tracks. Resulting ice sheets will be formed in a successive series of overlapping ridges. The ice masses become stagnant when the storm track is displaced to a position where the supply of moisture is cut off. The return of the anticyclones to their most favored locations with reference to the land distribution and elevation corresponds in time to the recession of the ice sheets. Recurrence of glacial periods will take place until erosion, uplift, or submergence change the size, shape, distribution, or elevation of the land masses or ocean basins. When such change attains a critical magnitude, the glacial cycles may be interrupted or terminated.

OCOEE SERIES OF THE SOUTHERN APPALACHIANS

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The Ocoee series is divided into four major units which are correlated from northern North Carolina to western Georgia, with a fifth formation present only in the Murphy syncline. The units are:

Ocoee series Late pre-Cambrian	Valleytown formation Big Butt quartzite Nantahala slate Great Smoky quartzite Hurricane graywacke
	UNCONFORMITY
Early pre-Cambrian	(Injection complex)

The series is a broad synclinal belt of resistant Great Smoky quartzite with Nantahala slate in deeper synclines, which forms the Great Smoky and Bald mountains. The Big Butt quartzite caps the Bald Mountains and occurs also in the Murphy syncline, where it is overlain by the Valleytown formation. The Nottely quartzite and Murphy marble, which overlie the Valleytown, are regarded as probably Lower Cambrian.

The Ocoee series is thrust westward on the Great Smoky overthrust over Paleozoic rocks of the Great Valley and in eastern Tennessee overrides unmetamorphosed sandstone, shale, and limestone previously included in the Wilhite slate. These rocks contain Ordovician fossils and are a clastic shore facies equivalent to the Tellico sandstone of undetermined stratigraphic range. Windows in the Great Smoky block expose limestones of the Ordovician ? series, previously mapped as Wilhite and Hiwassee slates of the Ocoee series. The Ordovician ? series and underlying rocks are in the Pulaski overthrust block which forms a wide belt in the region southwest of Newport, Tenn. Because the Great Smoky overthrust increases in horizontal throw southwestward, the thrust overrides and conceals the Ordovician ? series and the Pulaski block at the Georgia line.

MOLLUSCAN FAUNULE FROM DEVONIAN ISLAND MESA BEDS, ARIZONA

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Island Mesa beds contain a rather fragmentary but exceptional faunule of lamellibranchs and gastropods. Described in this paper are: (1) Mytilacea with acute carina and anterior lobe, both terminal, but also provided with a subumbonal myophoric depression as in the Dreissensiidae (not the "septum" auctorum, however, since the umbonal cavity is not developed below the myophoric depression notwithstanding its considerable elevation above the valve interior), to which was attached not only the anterior adductor, as in the latter family, but also, separated by a vertical ridge, the anterior retractor. Dentition represented only by weak posterior laterals; (2) Heavy-shelled pelecypods of unestablished relationship, of a circular outline, with a broad hinge plate carrying strong amorphous cardinals behind the anterior adductor, strong posterior laterals, and a narrow opisthodetic ligament; (3) Pleurotomariid gastropods of definite Devonian affinities; and (4) Trochiform gastropods with overlapping frills, comparable to the Visean *Luciella* of Koninck.

TERTIARY NONMARINE OSTRACODA FROM THE SALT LAKE FORMATION, NORTHERN UTAH

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A collection of nonmarine Ostracoda from the Salt Lake formation, Cache and Box Elder counties, Utah, is of interest because little is known of such fossils in the later Tertiary deposits of North America. Associated with the ostracodes are mollusks that are possibly late Pliocene, according to Teng-Chien Yen. The ostracodes are very different from and generally of more recent aspect than those occurring in the Paleocene and Eocene strata of the western interior region. The 12 described species, 11 of them new, include representatives of *Cypridopsis* Brady, *Candona* Baird, *Limnicythere* Brady, and two new genera. The latter exhibit aberrant characters not known by the writer to occur among Recent Ostracoda, and they perhaps represent a branch of candonids that were nearing extinction.

QUARTZ CRYSTALS WITH CLAY AND FLUID INCLUSIONS

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At several places in a narrow belt extending through Iredell, Alexander, Catawba, and Burke counties, North Carolina, quartz crystals with fluid and red-clay inclusions have been found. The rare and complex forms shown by the quartz, the inclusions of red clay, the large volume of water present in some cavities, and the presence of associated carbonate minerals all indicate an origin not far from the surface under conditions of relatively low temperature and pressure.

Since the crystals with fluid-filled cavities are destroyed by freezing and since they are found close to the surface in areas that have suffered practically no erosion since the Pleistocene, it is concluded that soil in the upper Piedmont of North Carolina was not subjected to deep freezing during the glacial stages.

EFFECT OF ATOMIC BOMBING ON BUILDING MATERIAL AT HIROSHIMA, JAPAN

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Field study of building materials at Hiroshima, Japan, was made in June 1946, more than 10 months after the atomic bomb devastated the area. The points of study had been untouched, and the materials were as undisturbed as when abandoned after the bombing.

The Imperial Government postoffice and telegraph building was almost directly below the position of detonation of the bomb. The building was crushed and disintegrated by concussion followed by a small fire. Two types of granite used in the foundation and trim of the building were sampled and studied for the effects of the stresses imposed at the time of the bombing. Dressed granite blocks 5 by 3 by 2 feet were so strained that much of the mass could be broken apart by hand and some of the interior of the blocks could be broken by a light-weight hammer. Some blocks of smaller dimensions had fallen apart at their resting place after the blast.

Characteristic shapes of the large disintegration fragments are partly those of spheroidal weathering, though crudely developed, and partly of forms made by shearing planes due to compressional stresses. Similar effects were observed on concrete, terra cotta, and other materials within a limited radius, but half a mile from the center of the area the standing buildings were found with sound masonry.

The possible effect of heat from the blast or subsequent fire is considered, and other observations are described; it is concluded that the compressional force of concussion was responsible for the major strain produced. Electroscope and Geiger counter tests were negative.

FORAMINIFERAL GENUS *Rzehakina* IN WESTERN EUCADOR

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Rzehakina epigona (Rzeh.) is frequently, sometimes even exclusively, found in the Paleocene Estancia formation of the Santa Elena Peninsula of western Ecuador. The formation consists mainly of massive hard greenish to gray micaceous sandstones alternating with blackish thin-bedded shales with a maximum thickness of 3000 feet, containing a poor assemblage of arenaceous Foraminifera (*Trochammina*, *Spiroplectammina*, *Bathysiphon*, *Haplophragmoides*, etc.) or is barren of organic remains. Good outcrops are found in the Anima, Alto, Chanduy, Estancia, and Verde Hills, west of Guayaquil.

The stratigraphic range of *Rzehakina* is confined to Maestrichtian, Danian, and Paleocene. The Venezuelan Oligocene *R. venezuelana* Hedberg is probably a *Massilina*. *Rzehakina* is recorded from: Maestrichtian-Danian of Trinidad; Danian-Paleocene Velasco formation, Eastern Mexico; Maestrichtian of South Dakota, Florida, Algeria, Catalanian Mountains of Spain, Morocco; Maestrichtian-Danian of Moravia, Atlantic Coast of Spanish Morocco; New Zealand; Danian of Smaller Pyrenees, France, Antarctic Burwood Bank; Paleocene of New Zealand, Northwest Caucasus, Ecuador, western Colombia (where it occurs with *Spiroplectammina* and *Vaginulinopsis* below transgression of Lower Eocene with *Discocyclina* and *Pseudophragmina*). Reworked specimens were found in Tortonian of Bologna, Italy, in Middle Eocene of Ancon area, Ecuador, and in possibly Eocene clays of Paita, Peru.

HETEROCHTHONOUS FORAMINIFERA IN RECENT SEDIMENTS (COLLUVIAL ASSEMBLAGES)

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Studies of large sets of recent beach-sand samples collected all over the Dutch East Indian Archipelago have convinced the writer that the actually living foraminiferal fauna is qualitatively rather poor. In each case the investigation of the formations outcropping in the hinterland and along the rivers watering into the sea is of utmost importance in differentiating biocoenosis and thanatocoenosis. Very few cases show that the heterochronous, allochthonous (or heterotopic) components in a beach sand are in reality reworked and re-embedded. The state of preservation of fossil specimens might even be as excellent as that of dead shells of recent forms.

The author proposes to call such adventitous components in a recent foraminiferal association colluvial (or ruderal) assemblages. Typical cases: lower course of small tributary of Sangkoelirang

River near Mandoko, E. Borneo (Neogene colluvial assemblage in recent river sands); coast of Jamdena, Tenimbar Island, near Wermatang (Plio-Pleistocene Foraminifera mixed into recent fauna); bottom core samples of Bay of Batavia, Java (mixed with Miocene and Pliocene of hinterland); beach at Pegatan, S. Borneo (colluvial well-preserved *Miogypsina* and *Lepidocyclina*); sediments of Nile River, Egypt (with excellently preserved Lutetian *Nummulites*); famous beach of Rimini, Adriatic Sea (with colluvial assemblages of Neogene from the subappennine hills), etc. Even occurrences of *Cycloclypeus* in recent sediments might be a case of heterochthony.

This phenomenon, however, has nothing to do with "stratigraphic condensation" whereby fossils (e.g., Ammonites) of different geological ages are found together without traces of reworking in the same deposit (e.g., Triassic of Timor, Central Himalaya, Middle Cretaceous of Swiss Alps, etc.).

Unless recent oceanographic bottom sampling proves beyond doubt the autochthony of its foraminiferal assemblages bathymetric conclusions and deductions in case of a fossil fauna will always have a certain degree of uncertainty or error, because a thanatocoenosis only indicates the quantitative and qualitative composition of a fauna but never its biologic, synecologic, and facies history. "Il tempo fa le pietre e poi le divora" (A. Silvestri, 1929).

MICROPALEONTOLOGY OF MIOCENE PROGRESO FORMATION, SOUTHWESTERN ECUDAOR

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As is the case with the Upper Cretaceous and Paleocene sediments of the Guayas province of southwestern Ecuador, the Miocene Progreso formation is extremely poor in microfossils, especially Foraminifera. A microscopic study of several hundred samples collected from the type section (cuts exposed along the modern highway south of railway station Progreso, leading to Playas) made up chiefly of friable brownish soft sandstone, silt, and shale was very disappointing because only eight samples yielded a highly impoverished assemblage of *Cibicides americanus* (Cushman), *Nonion sp.*, tiny *Globigerina sp.sp.*, and rarely a *Discorbis*, broken *Nodosaria*, and *Uvigerina* species. Few samples contained Ostracoda, remains of *Holothuria*, *Lamna sp.*, *Odontaspis sp.*, while fragments of horny substance and of Crustacea appeared sporadically.

The few samples with Foraminifera were rich in selenite indicating poor living conditions in a land-locked sea in a semimarine to brackish-water habitat. Interesting to note is the absence of reworked Foraminifera from older beds (foraminiferous Oligocene and Eocene) over which the Progreso transgression took place.

The Miocene Cardalitos and Zorritos formations of northwestern Peru are similarly poor if not barren in microfossils, while, in contrast, the Miocene sediments north of Santa Elena Peninsula, along Ecuadorian coast of Manta and Esmeraldas, and Tumaco region of southwestern Colombia appear highly foraminiferous.

NEW OCCURRENCES OF THE FORAMINIFERAL GENUS *Hantkenina* IN EUROPE AND ASIA

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During the last few years new occurrences of the time-stratigraphic important genus *Hantkenina*, a marker for Eocene, have been reported from Europe and Asia. Marie (1943) and Cuvillier (1945) found several species in middle Lutetian beds of the Tercis region, Landes, Aquitaine Basin; Di Napoli Alliata (1941) described two American forms (*dumblei* and *alabamensis*) from the Eocene of Gioitto (Enna) and Bronte (Catania) in Italy and confirms v. Hantken's (1844) discovery in the Eocene of Teolo, Euganean Hills near Padova, also mentioned by A. M. Davies (1934). The writer would place Teolo locality into the Middle instead of Lower Eocene (di Napoli).

In Yugoslavia (Dalmatia) the flysch sediments of Makarska and Omis (Keijzer, 1938; Rutgers, 1942; Van Soest, 1942), the Eocene beds of Sestanovac, Ljubuski, and Ričice near Imotski (De Witt

Puyt, 1941; Montagne, 1941; Van Bellen, 1941) all yielded upper and middle Eocene representatives of *Hantkenina*. Also important is the presence of the genus in the Eocene of Slatioarele near Pitesti, western Muntenia, Roumania (Fabian, 1944), and the finding of a fragment of *H. alabamensis* Cushman in the Upper Eocene (not middle) of Southern Limburg, Holland, the northernmost occurrence of the genus so far known (Van Bellen, 1946).

In Asia, *Hantkenina* was discovered in limestones of Upper Eocene age at Wai Tali, Cape Pasanea region, central part of the Island of Ceram (Germeraad, 1946). In East Borneo the writer's friend and colleague, the late Dr. L. A. J. Bakx, discovered during 1941 *H. alabamensis* Cushman and *H. inflata* Howe in at least 20 localities of Upper Eocene age along the upper reaches and tributaries of the Mahakam River, Long Iram area.

UPPER CRETACEOUS *Siphogenerinoide* BEDS OF NORTHWESTERN PERU

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Iddings and Olsson (1928) and Olsson (1934) subdivided the Upper Cretaceous sequence in the Amotape region, northwest Peru, into Pananga limestone at the base, followed by Copa Sombrero formation, *Clavulina* shale, and, at the top, Monte Grande formation. Wiedey and Frizzell (1939) added the Mal Paso shale as the youngest (Danian) formation.

The misnamed "*Clavulina*" shale is, in reality, a *Siphogenerinoides* shale (3000 feet or more), gray argillaceous, with occasional thin sandstone layers and dark-gray limestone concretions. Microfaunally it is mainly characterized by the abundance of several species of *Siphogenerinoides*, as *S. cretacea* Cushman, *S. whitei* Cushman, *S. bermudezi* Stone, *S. landesi* Stone, *S. reticulata* Stone, and *S. revoluta* Stone. This faunule is accompanied by other Upper Cretaceous forms, as *Anomalina semicomplanaa* Cushman, *Palmula primitiva* Cushman, *Haplophragmoides flagleri* Cushman and Hedberg, *Marssonella oxycona* (Rss.), *Dorothia* sp. cf. *D. filiformis* (Berthiaume), *Bulimina petroleana* Cushman and Hedberg, *Valvulineria depressa* (Alth), *Globorotalites*, *Bolivina*, *Frondicularia*, *Gavellinella*, and others.

The fauna has in general a Senonian aspect and is closely related to the possibly contemporaneous Colon shale of northwest Venezuela and northeast Colombia. Good outcrops of the *Siphogenerinoides* shale are found on the western side of the Amotape Mountains around Las Cruces, Pazul, and Redondo, especially in the Quebradas Chungo and Pazul Piura Department, northwest Peru). As a mappable stratigraphic unit it should be named after a geographic locality.

VALIDITY OF GENUS NAME *Nummulites* LAMARCK (FORAMINIFERA)

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To perpetuate the labors and efforts of the International Commission on Zoological Nomenclature attention is called to a very important recent decision regarding reinstatement of *Nummulites* Lamarck, 1801, Class Rhizopoda, order Foraminifera, as a validated genus name, suppressing therefore *Camerina* Bruguiere, 1789.

The case history, *Camerina* versus *Nummulites*, is embodied in Opinion 192, published August 21, 1945, in London. (*See:* Opinions and Declarations rendered by the International Commission on Zoological Nomenclature, vol. 3, pt. 11, pp. 139–156, 1945.) This decision certainly will be welcomed by all micropaleontologists and therefore needs wide divulgement.

A similar decision by the above-cited Commission is urgently needed regarding the reinstatement and validity of another foraminiferal genus, *Cristellaria* Lamarck, 1812, proposed by the writer (Eclogae geol. Helvetiae, vol. 30, pp. 344–346, 1937). This genus name would excellently serve as a *nomen collectivum* for such forms which cannot be placed under *Robulus* Montfort, 1808, or *Lenticulina* Lamarck, 1804.

FROHBERGITE, $FeTe_2$, A NEW MEMBER OF THE MARCASITE GROUP

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This new mineral was found associated with altaite, tellurbismuth, montbrayite, melonite, petzite, chalcopyrite, pyrite, marcasite, sphalerite, chalcocite, covellite, and free gold, in polished sections of the rich telluride ore from the Robb-Montbray Mine, Montbray Township, Abitibi County, Quebec. It appears in fringes surrounding chalcopyrite, also as inclusions in gold, petzite, or chalcopyrite. Color purplish pink, against the yellowish pink of melonite; reflection pleochroism not perceptible; anisotropism strong with polarization colors orange red to inky blue; hardness C; negative to standard etch-reagents except HNO_3 (1:1) which etches black with strong effervescence. Micro-samples show only Fe and Te by chemical tests; and x-ray powder photographs give a pattern identical to that of $FeTe_2$, the only known compound in the Fe-Te system, which was prepared for comparison by pyrosynthesis. Natural and artificial $FeTe_2$ give an orthorhombic unit cell with space-group $Pmnn$, $a = 3.85$, $b = 5.28$, $c = 6.26$, $Z = 2$, and observed intensities in good agreement with the marcasite type of structure determined on $FeTe_2$ by Tengnér (1938). Named after Dr. M. H. Frohberg, mining geologist, Toronto.

REEFS AND ISLANDS OF BIKINI, MARSHALL ISLANDS*

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U. S. Geological Survey

Systematic surveys made at Bikini before and after the recent atomic bomb tests (Operation Crossroads) afforded an unusual opportunity to examine the reefs and islands of one of the larger atolls of Micronesia. At 26 localities around the atoll detailed traverses were measured across the reef. They show the reef profile with its channels, pools, and caverns, the relative abundance of the important types of organisms, and the occurrence of sediments, making it possible to recognize on the ground the zonation that is clearly indicated on air photographs. There are striking differences between windward and leeward reefs, between seaward and lagoonward reefs, between reefs bordering islands and those that make up the wide stretches between islands.

By diving and swimming with face masks it was possible to examine deep pools in the blow-hole zone and the room-and-pillar structure that is locally developed beneath this part of the reef. The surge channels of the reef edge and the seaward slopes of the reefs themselves were studied by the same means. Parts of the lagoon floor and the coral mounds that rise from it were examined by diving.

Calcareous algae are widespread. They form a distinct *Lithothamnion* ridge along the seaward edge of the windward reefs, and *Halimeda* covers much of the lagoon floor. Corals and their near relatives are abundant, but their growth is not so prolific as that which characterizes the reefs in parts of the southwest Pacific. In spite of intensive collecting, several common coral genera were not found on Bikini. The species list, however, is large; a total of 115 have been identified to date by J. W. Wells, who is studying the collections.

NOTES ON DANISH AND SWEDISH GLACIALOGY

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In Denmark there are ground, terminal, and recessional moraines, outwash plains, and abundant erratic material from Norway, Sweden, and the Baltic Sea, made by actively moving glaciers. Two marine clays each separating till or outwash sheets and "hill islands" of till surrounded by younger

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outwash indicate that there were at least three Quaternary glacial epochs. At least one esker consists of a central "clay wall" of till apparently squeezed up into an open fissure in dead ice, bordered by steeply dipping sand and gravel deposits, and covered by horizontally stratified material. Another esker has no clay wall and is covered by till. "Tunnel valleys" and "clay plateaus" also indicate that the ice of the last glacier stagnated before it disappeared.

The Swedish eskers were deposited in the ocean, probably by moving glaciers, and were probably drawn out into long lines by retreat of the ice border. Sea level stood 150 meters higher than now and 100 meters above the tops of the eskers. The Uppsala esker is 147 meters high on one side and is mostly buried under younger marine deposits. Esker clay walls are unknown in Sweden. Through study of varves, marine erosional terraces on eskers, the spacing of moraines, and pollen analysis, the rate of glacial retreat and of postglacial land elevation, and also the postglacial climatic history of Scandinavia have been worked out.

There is still considerable difference of opinion among Scandinavians concerning the interpretation and correlation of varves.

FORM AND STRUCTURE OF SILLS

OGDEN TWETO

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Two structural types of sills have been recognized in the southern Gore Range, Colorado. In one the flow structure is about constant from contact to contact. In the other, linear mineral orientation near the contacts is at right angles to the orientation within the sill. This type also shows intrusive-stage folding, faulting, and brecciation.

The transverse linear orientation was produced by rotation of mineral grains as a result of differential movement in the viscous magma near the contacts. Rotation, folding, and flat intrusive-stage faulting indicate high viscosity, and the difference in structural types is attributed to difference in viscosity. As sills of the two structural types were intruded in about the same environment and had similar intrusive histories, the difference in viscosity was probably inherent in the magmas. Differences in textures and metamorphic effects support this conclusion.

Although relatively fluid magma is commonly supposed to form sills, and relatively viscous magma is supposed to form laccoliths, the opposite is true of the sills here considered. Sills showing evidence of low magmatic viscosity are the most irregular, and some of them bulge into laccolithic bodies; sills showing evidence of high viscosity are the most uniform and widespread. As highly viscous magma is unlikely to form uniform sills if it must lift the overlying rocks, intrusion was probably aided by the lifting action of arching competent beds. The relatively fluid sills were probably intruded without such aid and owe most of their irregularities to differential compaction of lenticular host rocks.

GEOLOGIC STRUCTURE AND DRAINAGE PATTERN IN NORTHEASTERN MINNESOTA

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The structure of the pre-Cambrian rocks in the region north of Lake Superior, in the northeastern part of Minnesota, including mainly Cook County, is responsible for the east-west alignment of lakes and streams.

The weaker Rove slate and associated resistant diabase sills, and the Keeweenawan flows, sills, and weaker interstratified sedimentaries, dip at a low angle toward Lake Superior. The Duluth gabbro, which underlies a large area, is banded; the weaker zones made up of easily weathered minerals such as olivine offer less resistance to the processes of erosion.

This structure was responsible for the development, in preglacial time, of a drainage pattern similar to that of the Ridge and Valley province in the Appalachians. Where the homogeneous rocks, such as the Saganaga granite, is present there is no alignment of drainage features.

Glaciation disturbed the preglacial drainage lines, but the alignment is still very conspicuous.

PRE-FOUNTAIN WEATHERING ON FLAGSTAFF MOUNTAIN NEAR BOULDER, COLORADO

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On the slopes of Flagstaff Mountain near Boulder, Colorado, the Fountain formation, a conglomeratic arkose of Pennsylvanian probably post Des Moines age, rests unconformably on pre-Cambrian Boulder Creek gneissoid granite. A weathered zone approximately 90 feet thick and having many of the characteristics of a laterite lies beneath the unconformity and was formed prior to the deposition of the Fountain formation. A deep-red, iron-rich rock at the top of the zone grades at depth into a mottled, light-gray to pinkish-gray, friable rock. This rock in turn grades into fresh granite or, locally, into a brown-stained rock which has acquired its color as a result of recent weathering. The recent weathering has not affected the thoroughly decomposed rocks in the pre-Fountain weathered zone.

Chemical and mineralogical analyses of 12 samples of fresh and altered granite are presented in tabular and graphical form to show changes resulting from pre-Fountain and recent weathering.

PALEOZOIC AND MESOZOIC COLUMNS IN THE GROS VENTRE, TETON, HOBACK, WYOMING, AND SNAKE RIVER RANGES, WYOMING

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The five mountain ranges adjacent to Jackson Hole in western Wyoming display remarkably complete Paleozoic and Mesozoic stratigraphic sections including all systems except perhaps the Silurian. Because the area is in a transitional position between a foreland facies with generally thinner sections to the east and a geosynclinal facies to the southwest and because the area was greatly shortened by a series of seven or more major overthrusts of Laramide age, the successions displayed in the several ranges differ markedly in thickness and in lithology at localities only a few miles apart. The entire Paleozoic-Mesozoic column ranges from about 5200 feet in the Teton Range to about 15,000 feet in the Snake River Range. This paper presents graphic detailed measured sections of nearly all parts of the column in each range measured during the past several years by students and staff members at Camp Davis. The following table summarizes the approximate thickness of the several systems in each range:

	Gros Ventre	*Teton*	*Hoback*	*Grayback Ridge*	*Snake River*
Cretaceous	9,816	Eroded	Eroded	5,200	4,800
Jurassic	925	450*+	1,112	1,366	1,500
Triassic	1,270	**	1,700	1,900	2,615
Permian	190	145	205	135	225
Pennsylvanian	750	750?	940	1,034	1,360
Mississippian	1,080	1,200	1,750	1,550?	1,800
Devonian	312	335	590	650?	850
Ordovician	350	280	130 exp.	60 exp.	730
Cambrian	853 exp.	850	unexposed	unexposed	1,180 exp.
			6427	11,915	15,060

* Top eroded.
** Not measured.

Diagnostic strata within the several formations, their persistence, and lateral variations are described. Eocene and Miocene sediments and volcanics of adjacent basins are not treated.

ALPHA-FOLDS

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Alpha-folds are those along the line of gliding or slip. Generally this line is not normal to the axis of common folding, but departs therefrom by 5°–30°. Whether initiated with the folding, or later, the departure generally is assignable to minor gliding across *b*, not to "rotational strain" in *ab*.

Beta-structures are those that the gliding crossed. Their inclination to alpha may indicate not a shift in the direction of advance (alpha), but a measure of the gliding across *b*.

Characteristics of alpha-folds are lateral symmetry and rarity of terminal plunge, features that extend to smaller folds on a larger one, and even to the striae. As best exhibited by the large "grooving" on an overthrust fault, their "fore-lobes," projecting into the foot wall, tend to be narrower and sharper than their "rear-lobes," which project into the hanging wall.

On bedding slips in anthracite and along foliation, the striae examined do not cut even paper-thin layers or mica flakes, but bend them. All the striae examined on bedding slips prove to be not "scratches," but alpha-folds.

GEOCHEMISTRY OF FLUORINE

B. WASSERSTEIN

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A semiquantitative spectrographic method circumvents the chemical difficulty of obtaining much-needed data on the distribution of fluorine in rocks. A systematic examination of South African rock types has been undertaken to trace the sources of fluorine in underground waters and so help those studying the incidence of endemic dental fluorosis, a disease attacking man and beast. About 250 spectrographic determinations have been made.

Fluorine appears to be a good indicator element for some petrological problems. As expected, marginal granites show high fluorine content (0.1 to 0.3%), whereas the centers of well-eroded batholiths give low figures (0.05% and less). Bushveld felsites (±0.04%) contain less than their associated granites (0.1%). Investigations of sediments and soils have also increased our knowledge of the geochemical cycle of the element.

The conclusion is reached that fluorine is more common than is recognized and that the abundance figure accepted by present-day authorities for the lithosphere viz. 0.03%, should be doubled—and possibly trebled. This work has not yet been completed.

BASE OF THE CAMBRIAN SYSTEM*

HARRY E. WHEELER

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In the western part of the Great Basin many thousand feet of marine strata lie conformably beneath the basal Cambrian faunal (time) horizons. Along the trends of transgression these basal deposits are progressively omitted until Lower Cambrian, and finally Middle Cambrian faunas occur in the beds which lie directly upon Archean and Algonkian rocks. Thus, on the basis of the basal unconformity, the beginning of Cambrian time varies with the locality, from the age of the strata at places where the faunally and physically established bases coincide, to the earlier but undeterminable age of the lowermost of any strata elsewhere conformably underlying. This variable duration of the "Lipalian interval," together with other similar Cambrian and post-Cambrian relationships, proves the inadequacy of diastrophism as a basis for subdivision of the time-stratigraphic column.

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Since faunal correlation is much more precise than diastrophism as a time index, the time-rock units of that portion of the geological record in which diagnostic faunas occur (Paleozoic and higher) should be delimited biologically. In the interest of local and interregional precision of definition, and validity of stratigraphic concept, the base of the zone of *Olenellus* is proposed as the base of the Cambrian system.

BLUE RIDGE—A FAULT SCARP

WILLIAM A. WHITE

University of North Carolina, Chapel Hill, N. C.

The present Blue Ridge scarp was produced by a normal fault which probably was active in late Tertiary time. This fault has been named the Blue Ridge border fault. Evidence of its existence can be found along an almost straight line extending about 700 miles from the vicinity of Gainesville, Georgia, to northwestern New Jersey.

Throughout much of its length the Blue Ridge border fault seems to have utilized pre-existent structures of an older Triassic fault zone which borders the Blue Ridge scarp on the east.

The Asheville peneplain of the upthrown fault block is considered correlative with the Piedmont peneplain on the downthrown block. Both are probably correlative with the Schooley peneplain. The Asheville surface descends gradually from elevations approximating 2100 feet on the strath of the French Broad River near Brevard, North Carolina, to coalescence with the Piedmont surface southwest of Hightower, Georgia, at elevations approximating 1200 feet.

The higher mountains of the Blue Ridge Upland are pre-fault features of the ancestral Southern Appalachians, and such outlying ranges as the Brushy and South mountains of the upper Piedmont of North Carolina are their equivalents on the downfaulted block.

The higher mountains of the Southern Appalachians are located on the upthrown fault block in the region of the greatest uplift, but beyond the end of the fault, southwest of Gainesville, Georgia, the mountains were not uplifted and have relief above the Piedmont surface commensurate with that of the higher mountains above the Asheville surface.

PLANNED PEACETIME WORK IN MILITARY GEOLOGY*

FRANK C. WHITMORE, JR.

U. S. Geological Survey

Military geology as carried out in this country during the war consisted almost entirely of interpretation of basic geologic and soils data so as to give the armed forces needed information concerning terrain, location of roads and airfields, water supplies, and other aspects of areas which were anticipated as the sites of military operations. With the end of the war the emphasis has shifted to field investigation, and the peacetime applications of military geology are concentrated on procuring first-hand information for two purposes: (1) to gather economic data in occupied countries as a basis for reparations settlements; (2) to prepare geologic maps of military areas both in this country and abroad for use in military construction work. Both these operations are making available much information of great interest from the point of view of pure, as well as applied, geology. Research of this type is now being done by the U. S. Geological Survey and the Corps of Engineers in Japan, Korea, the Philippines, and Okinawa. Further work is planned for other areas in the Pacific region.

STRUCTURE AND STRATIGRAPHY OF THE SIERRA DE SANTA ROSA, COAHUILA, MEXICO

MAX E. WILLARD

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An investigation of the barite deposits of the Sierra de Santa Rosa in northern Coahuila was undertaken in 1945 by the U. S. Geological Survey and the Comite Directivo Para la Investigacion de los

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Recursos Minerales de Mexico. As part of this investigation an aerial reconnaissance was made of the entire range, and approximately 25 kilometers (15.5 miles) along the eastern end of the range was mapped on a scale of 1:5000.

The range trends northwest, has an average altitude of approximately 960 meters (3150 feet), and a relief of 500 meters (1640 feet). The crest of the range coincides closely with the strike of the axial plane of a large open asymmetric anticline that is overturned to the northeast. Small folds occur, particularly on the steep northern limb of the large anticline. Erosion at the southeast end of the range has exposed approximately 1280 meters (5199 feet) of Cretaceous limestone, calcareous shale, and sandstone, representing stages from Aptian through Maestrichtian. Fossils collected from the mapped lithologic units have been studied by R. W. Imlay, and the following correlations with the already named formations in Coahuila are suggested: La Mula shale; lower member of La Peña formation; unnamed shale (not mapped separately elsewhere but included in upper part of La Peña formation); Aurora limestone; Eagle Ford shale and Austin chalk; San Miguel formation and Olmos formation.

Two beds approximately 20–25 meters (66–82 feet) apart in the upper part of the La Peña formation contain mantose of replacement barite more or less continuous for at least 25 kilometers (15.5 miles) along their strike. The Olmos formation exposed along the northern base of the range contains a 1–2-meter bed of coal, and this bed continues to the north into the Las Esperanzas coal basin.

PERMIAN STRATIGRAPHY OF SOUTHEASTERN ALASKA*

JAMES STEELE WILLIAMS AND JOHN C. REED

U. S. Geological Survey, Washington 25, D. C.

In southeastern Alaska rocks of definite Permian age occur at many places on the larger islands. They have also been reported from local areas on the mainland. Other rocks largely of metamorphic and igneous origin but including some conglomerates, cherts, and thin limestones may be in part of Permian age, but diagnostic fossils have not as yet been found. These are most widespread on the mainland.

The known Permian rocks of most areas may be divided into two units: a lower unit composed mainly of olive-brown and gray sandstones and sandy limestones, dark shales, and conglomerates; and an upper unit composed mainly of light-tan or cream to white thick-bedded medium to finely crystalline limestones and dolomites with which lenses and beds of white chert are commonly associated. Rocks of igneous origin, including andesitic and other tuffs, breccias, and agglomerates, and basic lava flows, form conspicuous parts of the lower unit. Limestones of Mississippian age commonly underlie the Permian beds, and sedimentary rocks of Triassic age overlie them. Several stratigraphic sections of Permian rocks were measured by the writers in 1940, and collections of invertebrate fossils made in connection with the field work as well as many collections made in previous years by geologists of the Geological Survey were located in these sections.

This investigation is part of a study of the stratigraphy and invertebrate paleontology of the Carboniferous and Permian rocks of Alaska, which was begun several years ago and is being carried on by James Steele Williams and several associates. Field work in southeastern, central, and eastern Alaska is nearly completed.

Spirifer rockymontanus MARCOU FROM THE TYPE AREA*

JAMES STEELE WILLIAMS

U. S. Geological Survey, Washington 25, D. C.

Marcou described *Spirifer rockymontanus* from "Tigeras, Canyon of San Antonio, New Mexico". Bed-by-bed collections made in 1946 from the type locality show that this species has a much greater range in variation than is generally attributed to it and that certain forms now considered separate species from *S. rockymontanus* should be more logically considered as mere varieties having little distinct stratigraphic significance.

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CHANNELS AND CHANNEL-FILLING SEDIMENTS OF RICHMOND AGE IN SOUTH-CENTRAL TENNESSEE

CHARLES W. WILSON, JR.

Nashville, Tennessee

During the post-Maysville, pre-Richmond interval a southeastward-flowing stream on the southeastern flank of the Nashville dome cut the Pulaski Channel in Giles and Lincoln counties, Tennessee, for a known length of 32 miles and with average width of 1500 feet and depth of 100 feet. During the Richmond this channel was filled with clastic sediments brought in from the southeast by the advancing Richmond sea. About 75 feet of Lower shale and Conglomeratic sandstone was deposited during the first, or estuarine, phase. Lenses of Lower limestone conglomerate consisting of pebbles and cobbles of older underlying limestone in a matrix of sandstone were deposited during this phase. The second, or marine, phase began when the Richmond sea invaded the region and submerged the channel now three-quarters filled with estuarine sediments. Along the submerged channel a total of 70 feet of Upper limestone conglomerate, Upper shale, and Sandstone member of the Mannie shale was deposited contemporary with the accumulation of about 45 feet of normal Richmond over the surrounding region, consisting of Fernvale formation, Mannie shale, and Sandstone member of the Mannie shale. The Upper limestone conglomerate, which is equivalent to the Fernvale limestone member, was deposited upon the upper slopes of the channel and upon the top of the Lower shale. The submerged channel was filled flush with the surrounding sea floor by the Upper, or Mannie, shale.

At the same time the Fayetteville Channel in Lincoln County underwent a similar history, but the sediments filling this channel are too poorly preserved to permit satisfactory investigation and interpretation except by analogy with the Pulaski Channel.

DISPERSION-BIREFRINGENCE RATIO AS A DIAGNOSTIC

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American Cyanimid Company, Stamford, Connecticut

The ratio between the dispersion of the birefringence ($B_F - B_C$) and the birefringence (B_D) is an optical property which is almost unknown, but it may be useful in certain cases. For example, a three- (or four-) component system may have physical properties such that "contour" lines for the commonly used physical characters, such as specific gravity, refringence, and birefringence, are all nearly parallel, but the lines for the dispersion-birefringence ratio seem to be far from parallel with the other lines in some cases. A few examples are given.

LUDLAMITE FROM NORTH GROTON, NEW HAMPSHIRE

CALEB WROE WOLFE

Boston University, Boston, Mass.

Ludlamite, hydrous iron phosphate, has been found as crystals in small veins in triphyllite at the Palermo Mine, North Groton, New Hampshire. *Habit:* platey $\{001\}$. Forms: c $\{001\}$, a $\{100\}$, m $\{110\}$, l $\{011\}$, q $\{\bar{1}11\}$.

X-ray data: Powder pictures of the Palermo material are identical with those of the type Cornwall material and of the Hagendorf, Bavaria *Lehnerite*. Rotation and Weissenberg pictures about [010] and [001] give: Space group P $2_1/a$; $a_0 10.48 \pm 0.06$, $b_0 4.63 \pm 0.05$, $c_0 9.16 \pm 0.06$, $\beta = 100°36'$; $a_0:b_0:c_0 = 2.26:1:1.98$. Analysis by Flight on type ludlamite gives irrational cell contents. From cell volume and G. = 3.08 measured on one crystal $M_0 = 815.6$. If cell contents were $Fe_3(PO_4)_4 \cdot 6H_2O$, a molecular weight of 817.1 would be obtained, and this composition is tentatively assigned the mineral. An analysis of the Palermo ludlamite is forthcoming.

Opt.: Biaxial positive; 2V 80°; α 1.650, β 1.667, γ 1.688. $r > v$ slight.

Occurrence: Transparent green crystals of ludlamite line narrow veinlets in triphyllite. Later minerals deposited in the cavities are, in order of deposition, fairfieldite in sheaf-like aggregates; vivianite in crystals coated with unknown white fibrous mineral; reddingite in orange-brown crystals; stewartite (?) in platey orange-brown crystals; and a biaxial white fibrous mineral with 2V about 80°, with positive optic sign, and with high birefringence, the indices ranging between 1.615 and 1.71. Only one specimen of the ludlamite has been found to date from Palermo, although another specimen from the Smith Quarry in Alexandria, New Hampshire, has been definitely established.

EARLY TERTIARY RODENTS OF THE FAMILY PARAMYIDAE

ALBERT E. WOOD

Amherst College, Amherst, Mass.

The Paramyidae (Upper Paleocene to Middle Oligocene) are discussed in detail, and the various genera and species revised. The family cannot have the fundamental ancestral position usually given it, since most members are too highly specialized. The fundamental division of the rodents into four suborders (Protrogomorphs, Sciuromorphs, Myomorphs, and Hystricomorphs) is reemphasized.

GLACIAL STREAM DIVERSION NEAR HORNELL, NEW YORK

ALBERT E. WOOD

Amherst College, Amherst, Mass.

A series of preglacial valleys near Hornell, New York, are blocked by glacial sediments, while new valleys have been cut through the rock walls on the east or southeast sides of the old valleys. The preglacial valleys are filled to considerable depths with sediments. The diversion valleys consist of two types: narrow, rock-walled and rock-floored valleys, apparently postglacial; and wider valleys, with rock buried (though not so deeply as in the original valley) and containing glacial deposits, apparently formed during an interglacial period.

MULTIPLE BANDING OF SEDIMENTS DEPOSITED DURING A SINGLE SEASON

ALBERT E. WOOD

Amherst College, Amherst, Mass.

The Arkport Flood Control Reservoir, near Hornell, New York, held water for the first time during the spring of 1940. This flood had three peaks, over a period of 2 weeks. The sediments deposited during this period form what appear to be three typical varves. Comparison of grain-size curves with those of varved deposits from proglacial lake sediments shows, however, a distinction between the two. A series of varvelike bands, not readily distinguishable from varves, may be deposited in a very short time and may by no means indicate the number of years required for the formation of a given deposit. Such a multiplicity of bands might not interfere with correlations, since the banding is determined by climatic variations likely to be fairly widespread.

REGIONAL GRAVITY SURVEY OF NORTHEASTERN UNITED STATES AND EASTERN CANADA

G. P. WOOLLARD

Woods Hole Oceanographic Institution, Woods Hole, Massachusetts

During the period 1942–1946 over 2000 gravity observations along profiles at approximately 10-mile intervals have been made in the area north of Washington, D. C., south of the St. Lawrence River, and from the Atlantic Coast westward to the Alleghany Mountains.

Bouguer anomalies, based on a density of 2.67, indicate marked variation in the thickness of the earth's crust and considerable lack of isostatic equilibrium.

GRAVITY AND MAGNETIC SURVEY OF CORTLANDT COMPLEX

G. P. WOOLLARD AND N. C. STEENLAND

Woods Hole Oceanographic Institution; Columbia University

In June 1946, 100 gravity and magnetic observations were made over the norite intrusion near Peekskill, New York, known as the Cortlandt complex. Residual Bouguer gravity anomalies based on a density of 2.67 indicate a gravity "high" of about 35 milligals centered over the complex with indications of two small local "highs" superimposed on the main one. A detached gravity "high" of about 15 milligals occurs in an adjacent area of Paleozoic limestone.

The results of the magnetic survey indicate a very complex field reflecting changes in magnetic susceptibility in the rocks in and off the complex, as well as polarization effects.

Neither the gravity nor the magnetic data indicate more than one main source for the intrusion.

SPATIAL ORIENTATION OF URANIUM IN SAMARSKITE

HERMAN YAGODA

National Institute of Health, Industrial Hygiene Research Laboratory, Bethesda, Md.

Alpha-ray patterns of polished samarskite sections prepared from crystals occurring in the Wiseman's mica mine, Mitchell Co., N. C., reveal marked variations of uranium content in symmetric growth zones which outline crystal faces. The polished sections appear to be optically homogeneous and show no evidence of foreign radioactive inclusions or internal alteration. Measurement of the photographic density of the alpha-ray patterns shows variations of about 25 per cent between zones of maximum and minimum blackening. Chemical analysis of the massive material reveals the presence of 0.8 per cent ThO_2 and 11.3 per cent U_3O_8. Assuming a homogeneous distribution of the minor amount of thorium, the variation in photographic density indicates variations in the uranium content of extreme zonal layers ranging between 10 to 13 per cent U_3O_8. Potential mechanisms for these unusual compositional variations are discussed.

CYCLOTHEMS, THE KEY TO LOWER PENNSYLVANIAN DIASTROPHISM IN NORTHERN NEW MEXICO

JOHN A. YOUNG, JR.

Syracuse University, Syracuse 10, New York

Strata deposited during lower Pennsylvanian time in northern New Mexico are the product of near-shore sedimentation. The rhythmic repetition of strata indicates that they are the result of cyclical sedimentation. Not less than 68 cyclothems occur in the Cortado formation in the vicinity of Taos, New Mexico, in the canyons of Rio Grande de Taos and Rio Grande del Rancho and their tributaries. Each cyclothem results from an interval of diastrophism which raised the Uncompahgre landmass and lowered the area adjacent thereto. The succession of lithologic units within each cyclothem is the result of the erosion of the uplifted landmass and consequent deposition of coarse clastic material, followed by deposition resulting from the formation and shoreward migration of a series of offshore bars.

PENNSYLVANIAN STRATA NEAR TAOS, NEW MEXICO: PRELIMINARY REPORT

JOHN A. YOUNG, JR.

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The stratigraphy of the Pennsylvanian sediments in the northern Sangre de Cristo Mountains of New Mexico is briefly described. At the bottom of the section, resting unconformably upon pre-

Cambrian igneous and metamorphic rocks, is a quartzite. A 25-foot bed of cherty limestone, tentatively correlated with the Whiskey Canyon limestone of Thompson, overlies the quartzite. A section of over 3300 feet of arkose, arkosic sandstone, arenaceous, carbonaceous, and calcareous shale, and a few thin beds of limestone rests upon the cherty limestone. These beds overlying the Whiskey limestone are herein designated the Cortado formation. They are arranged in a succession constituting 68 cyclothems. The Cortado formation is equivalent to Thompson's Armendaris group of the Des Moines series. Farther east, in the valley of Coyote Creek, north of Black Lake is more than 2200 feet of similar sediments, equivalent in age to Thompson's Bolander group of the Des Moines series. These strata are here designated the Cieneguilla formation. The upper beds of the Cieneguilla formation interfinger with the lower beds of a thick sequence of red arenaceous shale, correlated with the Sangre de Cristo formation. These red beds are at least 1921 feet thick, excluding that portion of them which is equivalent to the Cieneguilla formation. A thin limestone occurs 330 feet above the top of the Cieneguilla formation, and in the Sangre de Cristo formation. This limestone contains a sparse fauna, including *Mesolobus mesolobus*, indicating that the lower beds of the Sangre de Cristo formation in this region are of Des Moines age.

CONODONTS FROM THE SWEETLAND CREEK SHALE OF IOWA

WALTER YOUNGQUIST AND A. K. MILLER

State University of Iowa, Iowa City, Iowa

In the Mississippi Valley many of the shales near the Devonian-Carboniferous boundary contain few macrofossils, and opinions have varied widely in regard to the systemic position of these formations. However, conodonts occur in certain of the beds, and a particularly large and diversified assemblage has been secured from the Sweetland Creek shale. The general aspect of this fauna, and especially the abundant occurrence of the genera *Palmatolepis* and *Ancyrodella*, are suggestive of the Devonian.

ABSTRACTS OF PAPERS PRESENTED AT THE MEETING IN BERKELEY, CALIFORNIA, APRIL 19–20, 1946

Cordilleran Section of the Geological Society

PRE-CAMBRIAN GEOLOGY OF THE BAGDAD AREA, ARIZONA*

C. A. ANDERSON, E. A. SCHOLZ, AND J. D. STROBELL, JR.

Of 38 square miles mapped in the Bagdad area, Arizona, about two-thirds of the exposed rocks are of pre-Cambrian age. These were separated into units of bedded and younger intrusive rocks. The former (Yavapai schist) includes metavolcanics, metatuffaceous sediments, and metasediments in this stratigraphic sequence. The bedded rocks were folded and faulted before dike and sill intrusions of rhyolite, locally along faults in the Yavapai schist. Next, widespread invasion of heterogeneous gabbro took place, with minor intrusions along older faults. The gabbro includes anorthosite, anorthositic gabbro, diabase, and titaniferous magnetite lenses. However, some diabase is younger than the gabbro. Several large masses of alaskite porphyry were intruded into the Yavapai schist, rhyolite, and gabbro. Some of the volcanic rocks intruded by alaskitic magma formed mixed rocks or contaminated alaskite porphyry. Granodiorite was intruded next in the sequence. The igneous activity culminated in the large-scale invasion of granite, most of it porphyritic with large orthoclase phenocrysts. A younger facies of fine-grained granite is present in small masses followed by aplite-pegmatite in dikes and stocklike masses.

All of the above rocks except the granite and aplite-pegmatite have been metamorphosed, but the porphyritic granite is locally gneissic at some borders. The foliation in the bedded rocks is essentially parallel to the bedding even in minor folds.

PACIFIC NORTHWEST EARTHQUAKE OF FEBRUARY 14, 1946

J. D. BARKSDALE AND HOWARD A. COOMBS

At approximately 7:18:30 p.m. (P.S.T.) the Pacific Northwest was shaken by an earthquake of far more than average intensity. Two shocks, separated by a 30-second interval, originated from a provisional epicenter in the southeastern Olympic Mountains.

From preliminary investigations of damage done to buildings and from data supplied from questionnaires, the intensity ratings varied greatly, not only from city to city, but in various parts of the same city. In Olympia, the largest city near the provisional epicenter, the highest intensity reached was VII on the Wood-Neumann (1931) modified Mercalli scale. In Seattle and Tacoma the intensities locally reached VII. The most severe damage in Seattle was on deltaic and artificially filled land. Large cracks developed in brick buildings, plaster fell, and a few windows were shattered. Slightly lesser intensities were reported on the low, alluvial-filled portions of Seattle. The least intensities were on the hills of glacial drift.

An isoseismal map of Seattle and also one embracing all of Washington and Oregon is being prepared.

EFFECT OF HOT SPRINGS AND FUMAROLES ON GLACIAL TILLITE IN YELLOWSTONE NATIONAL PARK

CLYDE MAX BAUER

Several localities within the park where concentrations of tillite occur are described, and the character of the deposits is discussed. The processes of deposition and cementation are also analyzed.

PHYSICAL CHARACTER OF HOT-SPRING AND GEYSER DEPOSITS

CLYDE MAX BAUER

The behavior of a geyser or a hot spring is reflected in the structure of its deposits. The characteristics of sinter which reveal its history and indicate the nature and length of active and dormant periods are discussed.

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STRUCTURAL RELATION OF THE TEHACHAPI MOUNTAINS TO THE SIERRA NEVADA AND THE COAST RANGES

JOHN P. BUWALDA

The Tehachapi Mountains are not merely the southern end of the Sierra Nevada, as has commonly been supposed. Structurally they are more closely related to the Coast Ranges. They form a mountain mass which, unlike the Sierra Nevada, has not been tilted toward the San Joaquin valley but has been uplifted, with virtually no rotation, by faulting and warping along both its north and south margins. The Tehachapi Mountains trend somewhat north of east and can be considered one of the Transverse Ranges of the Coast Ranges; they are also structurally related to the east-west folds and faults of the Mojave Desert south of them. Mapping of the Mojave and Tejon quadrangles has shown that the east and east-northeast set of faults is intersected by northwest-trending fractures which as a system of faults and folds apparently extends from the Coast Ranges south of Coalinga beneath the San Joaquin valley and into the Tehachapi Mountains. While the Sierra Nevada have been largely a rigid block during post-Cretaceous time folds, faults, and unconformities between Tertiary formations indicate that the Tehachapi Mountains experienced moderately strong interna deformation during the middle and later Tertiary.

GEOLOGY OF THE MAGNESITE BELT OF STEVENS COUNTY, WASHINGTON*

IAN CAMPBELL AND JOHN S. LOOFBOUROW, JR.

The commercial magnesite deposits of Eastern Washington are confined to a single formation (Stensgar dolomite) of the Deer Trail group. This group is a series of metasediments, probably of Beltian age, composed dominantly of fine-grained clastics, with minor amounts of quartzite and dolomite, and totaling 5000 feet in thickness. Formations mapped within the Deer Trail group were the Togo formation (oldest), Edna dolomite, McHale slate, Stensgar dolomite, and Buffalo Hump formation. Lying unconformably upon these rocks is the Huckleberry group (Huckleberry conglomerate and Huckleberry greenstone). Unconformably above the Huckleberry group lies the Addy quartzite, which is probably Cambrian.

These formations, together with greenstone intrusives, have been closely folded. The dominant structure is the steeply dipping, locally overturned, west limb of a northward-plunging anticline. Longitudinal faults, probably high-angle thrusts, have caused parts of the section to be repeated in many places. Drag folds, indicating relative northward movement of westerly blocks, are conspicuous. Emplacement of a Cretaceous granitic batholith has considerably altered portions of the dolomitic and argillitic facies of the stratigraphic sequence, converting dolomite to diopside hornfels, and argillite to biotite-cordierite phyllite.

The magnesite is believed to be due to replacement of dolomite by hydrothermal solutions related in origin to the granitic batholith. Elsewhere in the area are deposits of barite, lead-silver, and possibly copper, which may be attributed to the same source.

Polaroid "vectographs", employed for the first time in areal geological work, greatly facilitated the mapping.

SOME STAGES IN THE GEOLOGIC HISTORY OF THE CHANNEL ISLAND REGION, SOUTHERN CALIFORNIA

THOMAS CLEMENTS

This paper is a progress report on a continuing study of the geologic history of the Channel Island region of Southern California. Four stages in the history are considered at this time, not because they are the most important, but because there is at hand more evidence concerning them. These stages are the Franciscan (Jurassic), Topanga-Temblor (Miocene), early Pleistocene, and later Pleistocene.

An attempt is made to work out the paleogeography of the four stages, using all of the various types of evidence available—that derived from a study of surface geology, of submarine geology, of paleontology, and seismology. The published writings of the many geologists who have worked in

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the region have been drawn upon freely, and the information so obtained has been augmented by the author's own work on the sea floor of the area.

The Franciscan was a time of general submergence of the Channel Island region, with the possible exception of the northern group of islands. The Topanga-Temblor, on the other hand, was a time of general emergence, again excepting the northern group of islands, which at this time were largely submerged.

Early Pleistocene was another period of emergence, with long southeasterly trending peninsulas, and fringes of islands extending out as far as 150 miles off the present shore. Later Pleistocene was again a time of submergence, with the sea encroaching on the present land areas and completely submerging some of the islands, while reducing many of the others in size.

GEOLOGICAL PROBLEMS AT ROSS DAM IN THE NORTHERN CASCADES OF WASHINGTON

HOWARD A. COOMBS

The city of Seattle has constructed a series of dams on the Skagit River in the northern Cascades. Ross dam, the northernmost of this series, will be one of the highest thin arch dams in the world when completed, and hence the geological conditions are of critical importance.

The rock in the vicinity of Ross dam is composed of granite, gneiss, and migmatite. Jointing, especially in the vicinity of minor faults, made necessary the removal of far more rock, locally, than had been anticipated when the original plans were drawn.

The first step of Ross dam was completed several years ago and floods the valley for 5 miles upstream; other dams flood the valley downstream. Thus an adequate source of aggregate for concrete was a problem.

A new type of vibration study was made at Ross dam in co-operation with the U. S. Coast and Geodetic Survey in connection with driving two power tunnels within 150 feet of the dam. As 800 pounds of powder were used in each charge some damage was anticipated if the second step was emplaced just before the tunnels were driven. It was finally decided, as a precautionary measure, to drive the tunnels before the second step was poured. The significance of the vibration data is not fully known as yet, but other studies of this type undoubtedly will teach us much about blasting in relation to large structures.

NEW GEOLOGIC DATA AT SULPHUR BANK, LAKE COUNTY, CALIFORNIA*

DON L. EVERHART

Sulphur Bank, in Lake County, California, has been a classic geologic locality since the days of Whitney and LeConte. Many geologists have studied the ore deposits, hot springs, and fumaroles there. Extensive open-pit mining for quicksilver ore during the World War II boom has exposed large areas of the rocks at Sulphur Bank mine and afforded an opportunity for the writer to observe geology of the Franciscan sediments which underlie the volcanics. The study was undertaken as one of the strategic-minerals investigations by the U. S. Geological Survey.

A brief description of the rocks and geologic structure at Sulphur Bank is given, and the important role of two intersecting fault zones in the structural control of the hydrothermal alteration and ore deposits is discussed.

IGNEOUS FUSION OF TUFF AT EUREKA, NEVADA

VINCENT P. GIANELLA

A rhyolite tuff at Eureka, Nevada, has been fused along its contact with a small plug of pyroxene andesite. For as much as 2 feet from the contact the tuff has been darkened and indurated through partial fusion with the formation of small irregular masses of dark glass. Tuff a few feet farther away appears to have undergone no change. The glass is black in hand specimens but is clear and colorless in thin sections. Occasional thin dikes of glass have penetrated the andesite. These have gradational boundaries with dark-brown glass along the margins. The brown glass appears to be due to mixing with fused andesite.

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The evidence indicates that fusion resulted from the action of hot gases rising along the contact after solidification of the andesite.

GENETIC RELATIONS OF MAGNETITE DEPOSITS OF THE RUNNING WOLF DISTRICT IN THE LITTLE BELT MOUNTAINS, MONTANA*

G. E. GOODSPEED

The principal iron deposits of the Running Wolf district are in the form of steeply dipping tabular lenses controlled by local fracture systems adjacent to laccolithic intrusions of syenite porphyry into limestone. The two largest of these lenses, on which exploratory work has been done, have strike lengths of about 1000 and 500 feet with average widths of 16 and 5.9 feet respectively. The dominant ore mineral is magnetite accompanied by varying amounts of specular hematite, and the gangue material consists of relic limestone, chalcedony, and jasperoid.

The gangue is indicative of hydrothermal deposition, and relic limestone strongly suggests that replacement was the dominant mechanism. Since the lenses dip away from the contact of syenite porphyry and limestone, and do not extend into the igneous rock, and because of the extreme paucity of contact-metamorphic minerals or deuteric alteration, the iron-rich hydrothermal solutions probably came from some deeper magmatic source as an end product of the crystallization of a basic magma. The former presence of such a magma is indicated by the general igneous rock relations of the region.

EFFECT OF GROUND-WATER TABLE ON BEACH EROSION

U. S. GRANT

Observations made in connection with a minor war project indicate that water seeping to the surface of the lower foreshore of a beach dilates the sediment and removes fine-grained particles. This dilated surface is very susceptible to wave erosion. When large waves, heavy rainfall, or wet-weather rills from the land back of the shore inundate the back shore the water table beneath the beach rises to the surface. This saturated condition of the beach greatly facilitates wave erosion. It appears to account for the rapid destruction of some California beaches when large waves occur at a time of a high water table under the beach. It also accounts for prominent local degradation of a beach in front of a small seep or miniature stream all of whose water may soak into the backshore sand. Lateral variations in the width of a beach can sometimes be accounted for by local variations in the position of the beach water table along a shore line. Care must be taken, however, to distinguish between local beach width variations due to this cause and variations due to local convergence and divergence of waves.

EFFECT OF TYPE OF WAVE BREAKING ON SHORE PROCESSES

U. S. GRANT AND F. P. SHEPARD

Observations on California beaches result in some apparently new interpretations of minor beach phenomena.

Oscillatory waves approaching a beach may break by a progressive spilling forward of the oversteepened crests, or they may break by plunging. In the latter case water at high velocity impinges on the sea floor, and much air is forced below the water surface. Upon rising, this air generates strong upward currents. These vertical currents transport sediment to or near the surface from which the sediment slowly settles to the sea floor. The long period of suspension of the sediment facilitates transportation toward or parallel to the shore.

This may explain the usual clear water and apparently insignificant transportation at La Jolla Cove, southern California, where waves do not plunge in contrast to the sediment-laden water and rapid sand transport a few miles north at and near the Scripps Institution of Oceanography where plunging of the waves is common.

This difference in character of breaking as well as convergence and divergence of waves are important factors in rate and type of beach modification.

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GEOLOGY OF THE EASTERN MARKAGUNT PLATEAU, UTAH

HERBERT E. GREGORY

The eastern Markagunt Plateau is a characteristic part of the extensive Markagunt Plateau: a high-lying eastward-tilted earth block outlined by the Hurricane and Sevier faults in Garfield and Kane counties, Utah. The exposed sedimentary rocks are of Tertiary age—representatives of the Wasatch, Brian Head, and Sevier River formations. Rocks of volcanic origin include porphyritic andesites, basalts of three different ages, and somewhat peculiar pyroclastics. Present volcanic activity is recorded in little-modified cones and long narrow lava streams.

EARTHQUAKES AND ASSOCIATED PHENOMENA IN THE ALPIDE BELT

B. GUTENBERG AND C. F. RICHTER

The distribution of earthquakes at depths less than 300 km., of active volcanoes, and of gravity anomalies in the Alpide belt of Eurasia shows relation to structural arcs analogous to that in the Circum Pacific belt. Shocks deeper than 300 km. are still unknown outside the Pacific belt. Where shocks at intermediate depths (70–300 km.) occur, they are most frequent near active volcanoes or sharp bends in the structures and are correlated with positive gravity anomalies.

GEOLOGICAL RECONNAISSANCE OF THE LOWER CHAPARRA AND ATICO VALLEYS OF SOUTHWESTERN PERU, SOUTH AMERICA

PAUL C. HENSHAW

The Chaparra and Atico valleys reach the coast of Peru at 400 and 470 miles respectively southeast of Lima. The following generalized geological observations were made during the course of detailed study of many mines and prospects in the area.

Carboniferous? volcanics, principally andesitic flows and tuffs, intruded by successive facies of a dominantly quartz monzonitic batholith, underlie most of the region. Pre-Cambrian gneiss crops out at the coast and again in the floor of Atico Valley. Early Paleozoic shales and quartzites which overlie the gneiss near Puerto Viejo appear as inclusions in the batholith near Convento. A graben in the lower reaches of Atico Valley exposes more than 6000 feet of Jurassic? red shales.

A thin veneer of mildly faulted, loosely consolidated Upper Tertiary sediments covers much of the seaward portion of a broad, gently sloping plateau. Northeastward, toward the interior, the plateau exhibits mature rolling topography. Small rhyolite flows from the northeast partly fill several of the mature highland valleys, while to the west they spread out to form an extensive unfaulted cover over the sedimentary veneer.

The Chaparra and Atico valleys, both with detritus-choked floors, cut deeply into the plateau. Remnants of a late rhyolite flow border the floor of the Upper Atico Valley. At the coast, marine terraces coupled with estuarine, littoral, and marine deposits indicate at least one stage of considerable depression and several stages of elevation subsequent to the initial great uplift of the area.

BASIN-RANGE STRUCTURE IN SOUTHWESTERN CHINA

CARLTON D. HULIN

The later geological history involving the development of fault-block valleys has been of extreme economic importance in southwestern China, since the best farm lands are invariably on the recently reclaimed alluvial fill forming the floors of these valleys.

The block faulting and development of Basin-Range structures disrupted an ancient erosion surface which truncates intensively folded and faulted strata ranging in age from pre-Cambrian to Triassic. Good evidence exists that this erosion surface had been uplifted and broadly arched prior to the inception of the block faulting.

The most visible result of the faulting was the widespread development of enclosed fault-block valleys. Typical are the valleys of Kunming, Likiang, Erhyuan, Tengchwan, and Tali. In some cases the valleys represent tilted fault blocks; in others the valleys are graben depressed between two or more parallel faults. The faulting in general is along north-south lines. Fault scarps are remarkably fresh and youthful in appearance, mountain faces along the scarps rising to 7500 feet or more.

These enclosed fault-block valleys were shortly occupied by lakes, the waters of which continued to rise until they overflowed the surrounding mountain barriers. Many of these valleys are still occupied by important lakes, but others have been drained more or less completely due to rapid deepening of outlet canyons. In most of the fault-block valleys it is apparent that the later stages of drainage and exposure of the valley floor have occurred during the period of human occupation and in part as a result of human effort.

Changes in the drainage pattern, induced by the faulting, have been so recent that frequently stable drainage lines have not yet been attained. In consequence there are physiographic problems of extreme interest.

MICA-BEARING PEGMATITES OF THE PETACA DISTRICT, NORTHERN NEW MEXICO*

RICHARD H. JAHNS

Dikes, sills, trough- and funnel-like masses, and more irregular bodies of mica-bearing pegmatite are abundant in eastern Rio Arriba County, New Mexico. They occur in an elongate area of pre-Cambrian schist, quartzite, metarhyolite, and granite. Most are discordant, with consistent westerly strikes, steep dips, and moderate westerly plunges. •They are conformable with many minor structures in the country rock.

Microcline and quartz, the chief pegmatite minerals, commonly form easily distinguishable zones within individual deposits. In general cores of massive quartz are surrounded successively by intermediate zones of coarse, blocky microcline or of massive quartz with giant microcline crystals, and by outer zones of fine- to coarse-grained microcline—quartz pegmatite with granitoid texture. The border selvages of a few deposits contain albite-oligoclase. Some of the cores can be traced along their strike into sulfide-bearing quartz veins, and offshoots from others transect the enclosing zones and continue into the country rock as typical veins.

Superimposed on the essentially concentric pattern of the zones are fracture fillings and fracture-controlled replacement bodies of quartz, cleavelandite, book muscovite, and other minerals, either singly or in combinations. These late-stage constituents are particularly abundant at and near the plunging keels of many pegmatite bodies. Accessory minerals include widespread spessartite, fluorite, columbite-tantalite, monazite, bismutite and other secondary bismuth minerals, beryl, and samarskite; sparse copper and iron sulfide minerals, uraninite, secondary uranium minerals, and ilmenite; and rare pink muscovite, apatite, lepidolite, and tourmaline.

STRATIGRAPHY AND STRUCTURE OF THE GALLINAS MOUNTAINS, NEW MEXICO†

VINCENT C. KELLEY

Pre-Cambrian gneiss and granite are exposed in several places in the Gallinas Mountains and are overlain by a thin Abo (Permian?) section, a clastic Yeso (Permian) section, and the Glorieta sandstone member of the San Andres formation (Permian). The absence of all the Pennsylvanian rocks and most of the Abo sandstone indicates that the Gallinas Mountains region was a positive area during Pennsylvanian and Permian (?) times. The basal rocks consist of about 100 feet of conglomerate and are overlain by as much as 1000 feet of sandstone, siltstone, shale, and discontinuous thin limestone beds all of the Yeso formation. In contrast to the Yeso to the west, south, and east, gypsum is absent from the Yeso of the Gallinas Mountains. The basal conglomerate and the littoral-zone nature of the Yeso further indicate proximity to a positive area during Yeso time. Although the positive area may have been overlapped in late Abo time, it affected sedimentation through Yeso time. The Glorieta sandstone section here is like that of the surrounding areas. In late Cretaceous or early Tertiary time laccoliths and sills were intruded into the sediments slightly above the contact with the pre-Cambrian rocks. The present Gallinas Mountains are the much-dissected remnant of the laccolithic mountains. Mineral deposits associated with the intrusions consist of iron, base metals, fluorspar, and bastnäsite, a fluo-carbonate of the cerium metals.

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TERTIARY MOONSTONE PEGMATITE

V. C. KELLEY AND O. T. BRANSON

The deposits occur along the west slope of the Black Range, Grant County, New Mexico. Scattered small bodies of pegmatite occur in a granite porphyry intrusive into quartz latite, both of Tertiary age. The pegmatite consists dominantly of quartz and sanidine with accessory quantities of albite, biotite, and sphene. Nearly pure masses of sanidine or quartz attain dimensions of as much as 4 feet. Sanidine anhedrons and euhedrons range in diameter from 2 to 12 inches. The sanidine displays blue and white opalescence giving rise to a moonstone of commercial quality. The quartz is very much fractured and ranges from clear to dark gray. Euhedrons of quartz are as much as 6 inches in diameter and 24 inches long.

Microcline is absent, and on the basis of the sanidine the pegmatite may be classed as a high-temperature type. The textural and structural evidence indicates that the pegmatite crystallized prior to the bulk of the granite porphyry. The pegmatites display three unusual, significant, and related features: (1) Tertiary age, (2) high-temperature mineralogy, and (3) early (phenocryst-stage) formation.

STRUCTURAL CONTROL FOR MINERALIZATION IN THE IRON SPRINGS DISTRICT, SOUTHWESTERN UTAH*

J. HOOVER MACKIN

Iron-ore deposits of the Iron Springs district are hematite-magnetite replacements in the Jurassic Homestake limestone around three quartz monzonite laccoliths. Exposed igneous cores average 5 miles in diameter. Except where faulted the intrusive contact is strictly concordant, lying at the base of the Homestake formation. The typical replacement ore body is an irregular lens 100–200 feet thick, with dimensions of 400–800 feet along the strike and dip of the limestone.

Flexing and faulting of roof and walls of the laccoliths during the principal period of intrusion were followed, after consolidation of a peripheral shell 100–200 feet thick, by a renewed surge of intrusion that developed a tight sheared zone between the solidified shell and the remaining magma. Cross joints in the shell are invariably barren, while cross joints of a later generation in the "interior" quartz monzonite generally carry magnetite and widen locally to form large magnetite fissure veins. Development of replacement ores along segments of the limestone contact where the peripheral shell is present was definitely contingent on breaching of the shell by breccia faults during the late intrusive surge. These fault zones served as conduits for mineralizing emanations moving outward from the "interior" quartz monzonite to replaceable limestone at the contact.

The peripheral shell is continuous only along steeply dipping lateral margins of the laccoliths. On the roofs of the laccoliths the shell is generally absent, and replacement ores were formed by emanations entering the limestone directly from joints in the "interior" quartz monzonite, without benefit of localized breccia feeders.

EQUILIBRIUM CONDITIONS IN STREAMS AS AGENTS OF TRANSPORTATION*

J. HOOVER MACKIN

Recent criticism of the Gilbert-Davis theory of grade requires a re-examination of this basic concept. The graded stream may be defined as *one in which, over a period of years, slope is delicately adjusted to provide, with available discharge and under prevailing conditions, just the velocity required for transportation of all of the waste supplied from the drainage basin.* The *delicate adjustment* differs in mechanism and detail from types of equilibria recognized in other sciences, but no more than these varied types differ among themselves. In stability under controls that are constant *over a period of years*, in sensitivity to change in controls, and in its ability to readjust to accommodate such changes, the graded stream exhibits the essential and diagnostic properties of equilibria in general. Load and discharge are not the only factors controlling slope, but they merit inclusion in the definition because they are the only controls which are, genetically, independent of the stream. *Slope* is not

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the only factor affecting velocity, but it appears to be the factor that is most readily adjustable to absorb effects of changes in controls. *Prevailing conditions* include the regimen of the stream and, especially, the trend and cross-sectional form of the channel.

Validity of the concept can be tested by considering (1) variations in the slope of the graded profile from segment to segment under stable conditions, (2) effects of changes in controlling conditions, including short-term reactions to changes introduced by works of man, and (3) long-term responses to analogous natural changes.

STRUCTURE OF THE INYO RANGE IN THE BISHOP QUADRANGLE AND ADJACENT AREAS

JOHN H. MAXSON

The Inyo Range is one of the largest Basin ranges, extending 150 miles in a north-south direction and rising to elevations of 10,000 feet above adjacent basins. The thick sedimentary section, in the Bishop quadrangle mostly of pre-Cambrian and Cambrian age, was folded prior to late Jurassic intrusion of granitic batholiths. In the north half of the Bishop quadrangle, a large syncline on the west side and a large anticline on the east side are virtually isoclinal and overturned to the east. These structures are not so tightly folded farther south in the range and plunge southerly. Though nearly parallel to the range trend, they are truncated obliquely to the south by faults blocking out the range.

Overthrust faults dipping to the east occur in the mountains west of the south end of Fish Lake Valley north of the Last Chance Range. The fault planes are displaced by later normal faulting.

The faults blocking out the range are en echelon and pass from basin floors to marginal position thence into the range. The interior of the range is intricately faulted, principally on northeast-, northwest-, and north-striking faults. Several periods of uplift on marginal faults are indicated by physiographic evidence. The range is crossed by the northeast-striking Deep Springs fault on which the south side has been uplifted and the pre-Cambrian section repeated. Deep Springs Valley is downdropped on this fault.

PETROGRAPHIC EXAMINATION OF CONCRETE AGGREGATES

RICHARD C. MIELENZ

Petrography may profitably be used in testing sands and gravels or quarried rock to be used as concrete aggregate. Aggregates constitute the preponderant bulk of concrete and therefore have a marked effect upon its strength, elasticity, durability, thermal properties, and unit weight. Consequently, most engineering organizations employ empirical tests intended to reveal the quality of aggregates and form a basis for specifications. All aggregates considered for use on Bureau of Reclamation projects are tested in the Denver laboratories; the empirical tests are always applied, but they are supplemented by petrographic examination performed by petrographers familiar with concrete and engineering problems. Through study of laboratory and field data, many petrographic properties of aggregates have been approximately correlated with the quality of concrete; at the present time, great reliance is placed upon petrography in the acceptance or rejection of proposed materials. Because of the large volume of aggregates requiring analysis, the petrographic study has been systematized for routine application.

Aggregates may affect concrete through either physical or chemical behavior. The most significant physical properties are: (1) abundance and nature of pores and fractures, (2) surface texture, (3) particle shape, (4) volume change with wetting and drying, and (5) thermal expansivity. Important chemical qualities are: (1) solubility, (2) nature of decomposition products, (3) reactivity with cement alkalies, and (4) base-exchange capacity. None of these properties is measured by the empirical tests; however, when applied by experienced petrographers, petrographic methods elicit information obtainable in no other way on a practicable, routine basis.

PROGRESS REPORT ON THE *Minerals of California* WITH NOTES ON SOME NEW OCCURRENCES

JOSEPH MURDOCH

Check of the literature for California mineral occurrences has been completed and brought up to date. The general prospective plan for the new Bulletin is outlined, and the occurrence of several minerals new to California is noted.

Petalite and helvite have been found associated with spodumene, in a small pegmatite near Rincon, San Diego County, and a titano-niobate of iron and yttrium, possibly a new mineral, has been found in rough orthorhombic crystals in the Southern Pacific Silica quarry near Nuevo, in Riverside County.

NOTES ON THE MANZANITA AND NORTH MANZANO MOUNTAINS, NEW MEXICO

PARRY REICHE

The area discussed is part of the northeasternmost unit of the Basin and Range province. About 1200 feet of gently dipping Magdalena formation (Pennsylvanian) rests on peneplaned pre-Cambrian. A few miles west of the mountains disturbed Permian, Triassic, and Pliocene (?) sediments are exposed.

The pre-Cambrian includes: (1) several thousand feet of greenstones, chloritic schists, and basic metatuffs; (2) red and gray phyllites with associated schistose grits and quartzites correlative with the latter, forming two or more formations totalling 1–2 miles thick; (3) granitized rhyolites, aggregating 4000 feet or more, and (4) a granite stock. Dikes of diabase, granite, rhyolite, and several small serpentine intrusions complete the tally. Bedding and schistosity in the pre-Cambrian dip 50° to 80° S.-SE.; they are usually parallel, but locally their strikes (not dips) diverge as much as 20°. Fracture cleavage and plication in the phyllites are common. An angular unconformity within the clastic sequence indicates an early disturbance; the later-formed major structure is most simply interpreted as a fold overturned toward the north-northwest, with associated thrusting and intrusion.

Sedimentary evidence first noted by C. B. Reed indicates some uplift here or near by in pre- and in mid-Magdalena times. Later, the initial North Manzano Mountains rose on a steeply west-dipping thrust, very possibly of Laramide age. During the Tertiary, roughly north-south, high-angle normal faults outlined the west face of the present range. A fault scarp in the piedmont and seismicity farther west recently discussed by S. A. Northrop indicate continuing adjustments.

SWARM OF EARTHQUAKES IN LASSEN VOLCANIC NATIONAL PARK

HARRY B. ROBINSON AND PERRY BYERLY

During the last 3 months of 1945 a swarm of small earthquakes was recorded at the Mineral Seismographic Station. Five were strong enough to be felt at Park Headquarters. The total number of shocks recorded in October and November was 377. The S-P intervals as measured varied from 0.5 to 6.1 seconds, but the strong maxima were at about 3.0 and 2.2. By our usual formula these are converted to distances of about 15 and 11 miles respectively. These distances reach to Warner Valley and Lassen Peak respectively. Some of these shocks were recorded at the Shasta Station of the Coast and Geodetic Survey. For those for which we have readings the shocks with interval 3.0 at Mineral show intervals of 11.2 at Shasta while those of interval near 2.2 at Mineral show around 9 seconds at Shasta. These readings check the general Warner Valley region for the first type and a location near Lassen Peak for the second type.

From the geological point of view all these shocks probably originated within Lassen Volcanic National Park or its immediate vicinity. Possible sources are a number of known faults located within an average radius of 15 miles from the Mineral seismograph station. The most likely source is the Warner Valley fault zone. Other sources include faults associated with the Brokeoff Mountain caldera and concentric faults associated with the origin of volcanic domes.

BRAUNITE FROM SNOWMASS, PITKIN COUNTY, COLORADO

AUSTIN F. ROGERS

Braunite, tetragonal, with the probable composition $3Mn_2O_3 \cdot MnSiO_3$, a comparatively rare mineral in this country, is recorded from a new locality in Pitkin County, Colorado.

It is a massive, somewhat granular, black metallic mineral which shows in cavities the pseudo-octahedral crystals so characteristic of it.

Associated minerals are calcite, barite, a pleochroic mica [probably manganophyll (manganian

biotite)], muscovite, quartz, microcline, and plagioclase; the three latter and probably the muscovite are detrital.

Calcite and barite are "persistent minerals" and thus give no clue to the type of deposit, but the presence of manganophyll points to a hydrothermal origin.

Attention is called to the importance of plane angles of crystal faces in the determination of minerals. Plane angles may be expressed as interzonal angles since edges of crystal faces are parallel to the corresponding zone axes.

ORIGIN OF SPHERICAL CLUSTERS OF ANALCIME, FROM OREGON

LLOYD W. STAPLES

An unusual occurrence of analcime has been found at Coffin Butte, Benton County, Oregon. Trapezohedrons of analcime are arranged in spherical clusters with hollow centers. Another zeolite, probably natrolite, occurs as needles completely enclosed within the analcime crystals and has a structure indicating that it originally radiated from the now hollow centers of the clusters.

The spherical clusters, which often appear only as rings of crystals, are not due to cyclic twinning. The arrangement of analcime crystals has been controlled by the radiating structure of the natrolite. Evidence to support this is obtained from a study of perched crystals of analcime on natrolite. The study also yields further data concerning selective incrustation, solution, and sequence of deposition of the zeolites.

FAULTING SEQUENCE IN THE NORTHERN BRISTOL RANGE, NEVADA

HARRY E. WHEELER

In the Paleozoic sediments and Tertiary (?) volcanics near Bristol Mine in the northern Bristol Range, Pioche district, Nevada, faults belongong to no less than six deformational epochs have been mapped, whereas only three such epochs have been reported previously. At least five of these epochs appear assignable to the Tertiary. Their character and order are as follows: (1) east-west normal faulting of possible pre-Tertiary age; (2) an undulating regional thrust by which the Devonian Silverhorn formation overrides Ordovician limestones and shales; (3) a north-south-trending, eastwardly dipping, medium-angle, reverse fault of large magnitude, throwing Middle Cambrian Highland Peak limestone in contact with the Ordivician strata; (4) northerly trending, west-dipping, normal faulting; (5) easterly trending, south-dipping, normal faulting; and (6) at least one epoch of late Tertiary, northerly trending, normal faulting, one displacement of which throws the Devonian rocks of the thrust nappe against Tertiary (?) tuffs at the western base of the range. This last is typical Basin-Range faulting.

As previously suggested by Westgate, probable post-Mesozoic age of the thrusting and later faulting is indicated by the involvement of the thrust with Tertiary (?) volcanics in the West Range, about 4 miles westward; absence of known faulting in the Pliocene (?) Panaca beds of the region suggests that all faulting ceased prior to Quaternary time.

Numerous small variably trending faults with less than 2000 feet of trace also have been mapped. However, these are regarded as sympathetic movements and minor adjustments within blocks and are not presently considered.

PRELIMINARY RESULTS AT STEAMBOAT SPRINGS, WASHOE COUNTY, NEVADA*

DONALD E. WHITE, PHILIP F. FIX, VINCENT P. GIANELLA, AND W. W. BRANNOCK

Investigations by the Geological Survey at Steamboat Springs reveal much new data. The springs, structurally related to recent faults on the east flank of the Sierra Nevada, appear genetically related to the magmatic source of very recent rhyolite domes in the area.

The geothermal gradient is very high, ranging from an average of 0.4° to 0.8° F. per foot of depth in two wells. Water analyses indicate a parent saline water diluted to varying degrees by water of low concentration; saline volcanic water is believed to mix with meteoric water near the surface. No known rocks in the region are considered adequate sources for the salts and metals contained

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in the waters. Heavy rains and possibly Steamboat Creek influence the springs. The discharges respond to barometric pressure, a relationship previously found only in wells piercing artesian aquifers, but artesian conditions are absent.

Associated gases are principally CO_2, H_2S, nitrogen, and minor oxygen, hydrogen, and argon. High-temperature vapors also contain mercury. Cinnabar, stibnite, pyrite, and other sulphides have crystallized at depths of 5 to 20 feet below the surface in sinter reworked after burial. Siliceous muds deposited from the springs contain gold and antimony equivalent to commercial ores, and also considerable silver, mercury, copper, and arsenic. The muds probably precipitate from the water at shallow depth and rise in mechanical suspension, largely during stages of high discharge; some precipitation may continue at the surface. Rock alteration is taking place, largely due to sulphuric acid formed by oxidation of H_2S.

Pacific Coast Branch of the Paleontological Society

NOTES ON THE GATUN FORMATION (MIOCENE), PANAMA CANAL ZONE*

A. MYRA KEEN AND THOMAS P. THOMPSON

Recent work in the type Gatun area indicates that at least 500 feet of Gatun strata lies below what has hitherto been taken as the base of the formation. The known thickness of the formation in the Canal Zone is thus increased to about 1200 feet. Faunally the type Gatun is divisible into three zones: (1) lower Gatun, containing 125 species of mollusks, 69 of which are restricted, 22 of which are new; (2) middle Gatun, with 115 molluscan species, 52 restricted, 4 new; (3) upper Gatun, with 41 molluscan species, 13 restricted, 2 new. Zone 1 as here revised lies entirely below the lower Gatun of previous workers (Woodring, 1928; Olsson, 1942); Zone 2 comprises the lower and middle Gatun of these authors; Zone 3 represents only the lowermost part of their upper Gatun.

The basal beds of the lower type Gatun rest upon a basement of basaltic rocks and volcanic tuff. They carry an abundant and well-preserved molluscan fauna of which a number of species are common to Horizon M-N of the Colombian Tuberá group. At this level also occurs a pelecypod of a subgenus, *Bornia* (*Temblornia*), known elsewhere only in the Round Mountain silt (Temblor) of California. *Cancellaria* (*Aphera*) *islacolonis* Maury, the zone fossil of the Cercado formation of Hispaniola, occurs somewhat higher, in the middle part of the lower Gatun. Therefore, the lower Gatun may be in part older than middle Miocene.

EVIDENCE OF TERMITES IN THE PLEISTOCENE ASPHALT OF CARPINTERIA, CALIFORNIA

JOHN P. LANCE

Fossilized fecal pellets of termites are found in pine wood preserved in the Pleistocene Carpinteria asphalt deposits, Santa Barbara County, California. Both pellets and wood are thoroughly impregnated by tar. This material is associated with characteristic plant remains found in the Carpinteria asphalt. The pellets resemble in size and shape those of the modern termites, *Kalotermes minor* and *Zootermopsis angusticollis* or *Z. nevadensis*. The distribution of these species today includes the Monterey Peninsula. Here a living Monterey forest assemblage of plants closely resembles that which existed in and about the Carpinteria asphalt accumulation during the Pleistocene.

NEW SHREW FROM THE NIOBRARA RIVER UPPER MIOCENE OF NEBRASKA

JAMES R. MACDONALD

A new shrew is described from the Upper Miocene Niobrara River fauna of Nebraska. This species shows closer affinities to *Crocidura* than does *Limnoecus tricuspis* Stirton, type of the genotypic species. Paleogeographic distribution of shrews is discussed.

MAMMALIAN FAUNA OF KUÇUK YOZGAT, TURKEY

JOHN H. MAXSON

In 1942 Dr. B. S. Tschachtli described a few teeth of *Hipparion gracile* Kaup and *Sus erymanthius* Ross and Wagner from a locality about 10 kilometers southwest of the village of Kuçuk Yozgat which is 40 kilometers east of Ankara, Turkey. Further studies and collections have been made at the locality by the writer. The fossils are broadly distributed in certain silty strata interbedded in a thick, nonmarine section of sandstones and conglomerates dipping generally south. The nonmarine formation lies in an intermontane basin northeast of Elmali Dag. The most concentrated occurrence is in a slightly indurated, fine sandstone containing fragments of clay throughout, suggestive of a quicksand. The bones are densely distributed and locally interlocked. A horse palate was found crushed into the carapace of a turtle. A fairly extensive collection has been obtained from this locality. A number of dentitions of *Hipparion gracile*, part of a ramus of *Sus erymanthius*, a variety of artiodactyl dentitions and horn cores, a skull of *Machaerodus*, and a skull and lower jaw of *Rhinoceros* form part of the collection. The fauna shows similarities with those of Saloniki,

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Samos, and Maragha. It also shows some relationship with the fauna of Kuçuk Çekmece but is possibly somewhat more advanced. The stage represented by the fauna of Kuçuk Yozgat is believed to be Pontian.

SIGNIFICANCE OF THE VERTEBRATE FAUNA OF KUÇUK CEKMECE, TURKEY

JOHN H. MAXSON

In 1933 A. Malik and Hamit Nafiz described a vertebrate fauna from estuarine beds on the shore of the Sea of Marmora near the village of Kuçuk Çekmece, about 18 kilometers southwest of Istanbul, Turkey. The original collection from Kuçuk Çekmece has unfortunately been lost by fire, but the writer has been able to secure a small representative collection by further excavation at the original locality.

The geologic section in the vicinity exposes Eocene limestone, overlain by a series of soft Upper Miocene sandstones and silts, overlain by younger alluvium. The fossils themselves occur in an unconsolidated, cross-bedded sandstone about 12 feet thick. This bed overlies a massive unfossiliferous siltstone and is overlain by an argillaceous sandstone. Marine fossils are intercalated with the mammal remains. Among them are bones of fish, cetaceans, and pinnipeds. Testudinate fragments are common. Fossil mollusks also occur in the vertebrate-bearing bed. The vertebrate fauna contains: *Mastodon pentelici*, *Rhinoceros pathygnatus*, *Hipparion gracile*, *Sus erymanthius*, various artiodactyls, *Mustella pentelici*, *Machaerodus orientalis*, *Steneofiber* sp. The fauna is related to the faunas of Maragha, Pikermi, and Salonica.

According to E. Chaput and S. Gillet, *Mactra bulgarica* and *Mactra caspia*, found in the vertebrate-bearing bed, are characteristic of the Chersonian (upper Sarmatian). This indicates that in eastern Europe *Hipparion gracile* occurs not only in the Pontian, *sensu stricto*, but also in the Maeotian and in the upper Sarmatian.

EOCENE FORAMINIFERAL FAUNA FROM CONTRA COSTA COUNTY, CALIFORNIA

P. ROSSELLO NICHOLSON

A foraminiferal fauna was collected about 2½ miles northwest of the town of Orinda, California, where the Bear Creek Road cuts through the Sobrante anticline. The core of this anticline is shown on the Concord quadrangle of the San Francisco Folio as the Tejon formation, but no fossils were cited. The Foraminifera were found in alternating beds of fine sandstone and silt near the top of the "Tejon" formation. This fauna contains 44 genera and 86 species including only part of the arenaceous forms. It has been compared to faunas of known stratigraphic position from the following localities: Potrero Hills, Shell Refinery, Putah Creek, Fenn Ranch, Marysville, Nortonville, Alhambra Creek (Pacheco syncline), Mt. Diablo, and Panoche Hills. It is of Eocene age. This fauna represents a facies which seems to contain forms that have been listed as guide species of various Eocene zones.

VERTEBRATE TRACKWAYS FROM THE LOWER TRIASSIC OF ARIZONA

FRANK E. PEABODY

Field work during pre-war days brought to the Museum of Paleontology of the University of California a fine collection of vertebrate trackways from the Moenkopi Lower Triassic of Arizona. Represented are stegocephalian amphibians and a variety of reptiles. *Chirotherium*, first known from the Lower Triassic of Europe, is the most common. It is represented by at least eight species. The trackways furnish an important record of the tetrapod fauna during Moenkopi time, because skeletal remains are scarce. The reptile trackways consist of two distinct types: quadrupedal lizardlike forms perhaps representing the Protorosauria; long-legged dinosaurlike forms showing a tendency toward bipedalism and probably representing the Pseudosuchia.

IS THE BLANCAN PLIOCENE OR PLEISTOCENE?

R. A. STIRTON

Recent publications by McGrew (1944) and Evans and Meade (1945) assign the Blancan to the Pleistocene epoch. The initiation of epirogenic movements in the earth's crust and the first ap-

pearance of late Cenozoic glaciation in Blancan time had been suggested previously; but since the type Pliocene (Lyell's Older Pliocene), as typified by the sub-Appennine strata in northern Italy (Astian—marine; Val d'Arno—fresh water), is a correlative of the North American Blancan, Pleistocene time was not extended to include this early glacial age. The writer favors the earlier arrangement as approved by the Committee on the Nomenclature and Correlation of the North American Continental Tertiary (1941) and consider the Blancan as Pliocene.

INCIDENCE OF DISEASE IN *Smilodon*

CHESTER STOCK

While the incidence of disease is high in the Pleistocene sabre-tooth, *Smilodon*, certain regions of the skeleton show lesions more frequently than others. Several factors appear to be involved, reflecting the habits and habitat of this animal.

MOENKOPI VERTEBRATES

SAMUEL P. WELLES

The Lower Triassic Moenkopi formation of northern Arizona and southeastern Utah has been prospected by parties from the University of California Museum of Paleontology since the summer of 1938. Fish spines, ganoid fish, labyrinthodont skulls, and isolated reptile bones have been collected. Among the labyrinthodonts, totaling nearly 30 skulls and 1 complete skeleton, are a number of capitosaur skulls and an *Aphaneramma*-like skull. A plagiosaurid lower jaw is the first record of the group from North America, and the genus *Cyclotosaurus* is recognized for the first time in the Western Hemisphere.

Reptile remains are fragmentary and include a maxillary of a pseudosuchian that seems to be ancestral to the theropods, an ilium that might be prophytosaurian, and several light, hollow limb bones. Tracks of amphibians and several reptiles have been collected; *Chirotherium* was found in both the lower and upper parts of the formation and is fairly common.

PRELIMINARY NOTICE OF A NEW MIOCENE VERTEBRATE LOCALITY IN IDAHO

JOHN A. WILSON

During the summer of 1941 the author investigated reports of the discovery of vertebrate fossils in the Lemhi Valley of east-central Idaho. The beds are intermontane and extend from the vicinity of Salmon on the north to an unknown distance south of Gilmore. In places they are overlain by Pleistocene and Recent alluvial fans and moraines but they outcrop intermittently over an area roughly 70 miles north-south and 5 miles east-west.

Those fossils collected by the author are tentatively identified as *promerychocherus* sp., *ticholeptus* sp., *parahippus* sp., and *alticamelus* sp. Others collected in the same area by Mr. Ralph Nichols of Grant, Montana, have been identified by C. L. Gazin as "rhino teeth," *Parahippus*, *Mylagaulus*, and *Merychyus*. From the above faunal list it appears that age of the beds is somewhere between Lower Miocene and Lower Pliocene, perhaps equivalent in part to the Payette of western Idaho.

ABSTRACTS OF PAPERS PRESENTED AT MEETINGS OF SECTION E, A.A.A.S.

St. Louis, Missouri, Meeting, March 27–29, 1946

HIGH-LEVEL CLAYS IN THE PORT HURON MORAINIC SYSTEM IN MICHIGAN

BY STANARD G. BERGQUIST

One of the most rugged areas in the Southern Peninsula of Michigan lies within the belt that was occupied by the ice which formed the Port Huron morainic system in late Wisconsin time. Field studies of this region reveal that the features of surface expression are merely reflections of an older topography that was buried under a relatively thin sheet of drift during the stage of development of the Port Huron-Manistee morainic systems.

Beneath the thin mantle of boulder clay and boulder sand that makes up the Port Huron drift is an old surface of high-level clay commonly exposed in road cuts and erosion channels. The clay is heavily jointed, blocky, well indurated, and chocolate-colored. In some of the deposits the clay is pebble-free and laminated, suggesting a lacustrine origin. In adjacent exposures the same type of clay contains well-rounded, smoothly polished and striated pebbles, characteristic of the type of material that Leverett has often referred to as pre-Wisconsin till in the southern part of the Peninsula.

Weathering makes the chocolate-brown clay mealy and changes it to a brick red color. In the deeper unweathered zones, however, the material is grayish blue and so compacted that it is difficult to remove with a pick.

Drumlins are widely distributed over the surface. They are not confined to till plains of Wisconsin deposition but are scattered through areas of moraines, outwash aprons, and lake plains as well. They are cored in the underlying indurated clay and were so thinly covered with drift of the Port Huron invasion that their outlines have not been completely obscured.

The surface expression of the region suggests that the readvancing Valders ice which formed the Port Huron system was either relatively thin or not very heavily loaded with debris.

GEOLOGY OF THE CAÑON CITY, COLORADO, AREA

BY VICTOR J. BLUM, S.J.

The paper presents detailed features of a portion of the Cañon City Embayment in Colorado. In this region, an area about 11 miles long and 8½ miles wide was studied during several summers of field work. The western half of the area investigated consists of pre-Cambrian granites, gneisses, schists, and pegmatitic intrusions. To the east of this ancient complex are the sedimentaries dating from Ordovician to Tertiary time. About Miocene time small igneous pipes pierced the sediments south of Cañon City. The area is rich in economic products and includes coal, dolomite, silica, feldspar, travertine, oil, beryl, and fire clay.

Although most of the sedimentary rocks of the area lie in one large syncline, which pitches to the southeast, there are many modifying structures like the thrust faults to the northwest and the southwest of Cañon City and the anticline to the southeast. Geophysical methods of investigation have helped to extend the trace of a vertical fault which forms the contact between the pre-Cambrian and the Mesozoic rocks south of the city.

Several maps prepared from reconnaissance and extensive plane-table surveys show the areal extent of the formations, their dips and strikes, and the location of many interesting geological items in the Cañon City area.

GEOLOGICAL AND GEOGRAPHICAL DISTRIBUTION OF CONODONTS IN THE MISSISSIPPI VALLEY

BY E. B. BRANSON AND M. G. MEHL

Slides will be presented showing Lower, Middle, and Upper Ordovician conodonts; Lower and Middle Silurian conodonts; Middle and Upper Devonian conodonts; Lower, Middle, and Upper

Mississippian conodonts; Lower, Middle, and Upper Pennsylvanian conodonts; Lower Permian conodonts. Evolutional changes and uses of conodonts will be discussed.

LOWER MIDDLE ORDOVICIAN (LOWVILLE) CONODONT FAUNA FROM TENNESSEE

BY E. B. BRANSON, M. G. MEHL AND C. C. BRANSON

A conodont fauna consisting of a large number of old and new species of known genera from the Carters formation of Tennessee is to be presented with slides and discussion. The fauna seems to be intermediate between that of the typical Dutchtown of Missouri and the Joachin. It lacks representatives of such typical genera as *Multioistodus* and *Erismodus* of the former and *Dichognathus* and *Phragmodus* of the latter.

PROBLEMS OF CORRELATING PENNSYLVANIAN ROCKS AT THE SURFACE IN NORTH-CENTRAL TEXAS WITH SUBSURFACE OF ADJOINING BASIN AREAS

BY M. G. CHENEY

(1) During Pennsylvanian time a number of extensive uplifts and subsidences occurred in north-central Texas. Maximum differential movements developed between earliest Lampasas and latest Strawn times. Sedimentary wedges having composite thickness of 10,000 feet in the Fort Worth-Cisco section diminish by truncation and nondeposition to about 1000 feet in areas of greatest uplift 100 miles to the south and north. Variables involved cause difficult problems of correlation and classification.

(2) Rocks of Springer age have not been reported at the surface; outcropping Morrow and Lampasas rocks are limited in area and variable in character; younger Pennsylvanian rocks are well represented in areas of outcrop but show considerable lateral variation in character and thickness. This is especially true of the Strawn series (Allegheny equivalent).

(3) Various lithologic and faunal changes occur in the subsurface, especially in post-Morrow beds; clastics predominate to the east, limestones and dark calcareous shales to the west.

(4) Separation of Morrow and post-Morrow limestones, occurring in a continuous sequence at Marble Falls and in some subsurface areas, has proved difficult partly because of lithologic similarity.

(5) Westward loss of Morrowan limestones has been less readily recognized because upper Big Saline shales change to limestone westward to offset loss of these lower Marble Falls beds. The name Big Saline group has been proposed for post-Morrow pre-Smithwick beds. In much of this region chert conglomerates mark the base of the Big Saline. These conglomerates thicken northward and contain arkoses around the Muenster arch and limestone fragments in the Bostwick beds of the Ardmore basin.

(6) Above the Big Saline the prevailing black shales of the Smithwick outcrops near Bend evidently change to black and gray limestones to the northwest in the subsurface.

(7) Absence or scarcity of characteristic *Fusulinella* in the thickening Big Saline and Smithwick sections to the east increases the difficulties of correlation in that direction.

(8) Confusion has arisen from diverse use of the names Bend and Bendian to include (a) upper Mississippian, (b) Stanley-Jackfork, and (c) Parks group of the subsurface as well as (d) Marble Falls and (e) Smithwick beds of the outcrop area. In recent usage the Bend has included (c), (d), and (e) in subsurface but only (d) and (e) at the outcrop.

(9) The economically important Parks group appears to thicken from a few hundred feet in subsurface to 1500 feet in the Brazos River section where fusulinids of the subsurface Parks group occur as high as the Dennis Bridge limestone. In subsurface this group appears more related lithologically and structurally to the Smithwick than to the overlying Strawn beds. Change from 1500- to 400-foot thickness and less in the Colorado River section and in the oil fields of north-central Texas needs further study. Deference to practical and long-established usage of petroleum geologists in north-central Texas, as well as to the present trends in placing the Pottsville-Allegheny boundary just below Kittanning beds in the type Pennsylvanian section, would favor inclusion of the Parks group in the Lampasas series, making the latter closely equivalent to the Kanawha series of the Appalachian. Most fusulinid species in upper Parks beds are transitional from *Fusulinella* to *Fusulina* types.

(10) Recognition of a low-angle unconformity and the well-known Des Moines-Missouri faunal break at the base of the Lake Pinto conglomerate permits more reliable subsurface correlations and serves as a more useful boundary between the Strawn and Canyon series than did the former higher boundary between the Strawn and Canyon groups based on local lithologic differentiation.

(11) Extensive channelling and widespread prevailing rock differences separate the long-established Canyon and Cisco divisions at a time boundary related to post-Hoxbar Arbuckle orogeny and to the Missouri-Virgil hiatus of the northern Mid-Continent. Variations associated with reef-limestone developments, particularly in the Canyon beds, present local problems of correlation in surface and subsurface.

(12) Agreement with the standard Permian system of West Texas evidently requires placing the Pennsylvanian-Permian boundary from 50 to 100 feet below the Saddle Creek limestone in north-central Texas.

ROLE OF MICROFOSSILS IN INTERREGIONAL PENNSYLVANIAN CORRELATIONS*

BY CHALMER L. COOPER

In the past the use of microfossils for long-distance correlations has been somewhat restricted, especially in the Carboniferous, owing largely to the paucity of workers interested in this class of fossils. Previous work was centered largely on the fusulines and ostracodes, and papers on these fossils were confined largely to the Midcontinent, while those on other Foraminifera and conodonts are represented by relatively few papers from much the same area. More recent work on microfaunas from formations in the Eastern Interior Basin and the West has shown that microfaunas, particularly the ostracodes and some Foraminifera, can be utilized as valuable tools in stratigraphic work.

SPORE FLORAS OF THE PENNSYLVANIAN OF WEST VIRGINIA

BY AUREAL T. CROSS

Examination of the macerated residues from most of the coal horizons of the Kanawha and Lower Allegheny series has revealed that megaspore assemblages are of value as an aid in correlation work. Preliminary studies are admittedly inconclusive, but at the present time these fossils indicate major floristic changes above the East Lynn sandstone, and below the Coalburg coal, the Dingess shale, the Matewan shale, and the Eagle shale. Microspores appear to show more clearly minute fluctuations of the vegetation. Minor floristic changes evident during short intervals of time have not been readily correlated regionally and may represent local geographic and ecological variations. More than 70 species assignable to 18 genera have been tentatively identified. The index value of a number of these is illustrated.

STRATIGRAPHY AND STRUCTURE OF PHOSPHATE ROCK NORTHEAST OF GEORGETOWN, IDAHO†

BY CHARLES DEISS

The Deer Creek-Wells Canyon district includes 18 square miles in the northern part of the Preuss Range 12 miles northeast of Georgetown, Idaho. The phosphatic member of the Permian Phosphoria formation is composed of siltstones, limestones, and shales interbedded with phosphate rock. The member, 179 to 200 feet thick, underlies the Rex Chert member and overlies the Pennsylvanian Wells formation.

The phosphate rock is black to brown gray and consists of collophane oölites, pisolites, and nodules embedded in fine-grained collophane mixed with silt, clay, and calcite. Most of the phosphate rock occurs in three zones, here named the Lower, Middle, and Upper phosphate zones. The Lower phosphate zone contains the thickest persistent beds of high-grade rock (70 per cent or more B.P.L.). The Middle zone contains only medium- (50–69 per cent B.P.L.) and low-grade (30–49 per cent B.P.L.) rock. The Upper zone is the thickest and contains much high-grade rock which, however, is separated by irregular beds of siltstone, limestone, and low-grade ore.

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The geologic structure comprises three major folds which strike N. 15°–23°E. and are broken by overthrusts and normal faults. The folds, from east to west, are the Webster syncline, Snowdrift anticline, and Georgetown syncline. The phosphatic member appears as four subparallel belts, one on each limb of the synclines. Many normal faults and four or more thrusts break the phosphatic member. The faults are more numerous in the Georgetown than in the Webster syncline.

INDUSTRIAL MINERALS OF OKLAHOMA

BY ROBERT H. DOTT

Oklahoma has an economically important combination of certain industrial minerals and low-cost fuel: coal, natural gas, and petroleum. In the Nation's production of 1942, Oklahoma ranked among the first six States in volume and value of: zinc and zinc-lead ores and recoverable metals; native asphalt; liquified petroleum gases; petroleum; natural gasoline; and natural gas.

Reserves of some important minerals are measured in billions: bituminous coal—55 billion tons; gypsum—125 billion tons; natural gas—6500 billion cubic feet proven; petroleum—1 billion barrels proven. Others known to exceed 1 billion tons are: dolomite; glass sand; high-calcium limestone; granite and anorthosite; and rock salt.

In addition, the following are of economic importance, present or potential: grahamite and impsonite; ceramic clays; moderate amounts of iron ores; metabentonite; oil-field brines; milky quartz; tripoli; volcanic ash; and woolrock.

REVIEW OF STUDIES OF PLEISTOCENE DEPOSITS IN KANSAS

BY JOHN C. FRYE

The existence in Kansas of both glacial and nonglacial deposits of Pleistocene age was recognized more than half a century ago. Since then many geologists have been concerned with these deposits, and more than 100 papers dealing wholly or partly with the Pleistocene of Kansas have been published. This paper summarizes the work so far accomplished. The State is considered in five districts: (1) the glaciated area in the northeast, (2) the east-central and southeastern area, (3) the central and south-central area, (4) southwestern Kansas, and (5) north-central and northwestern Kansas. Although recent work has resulted in extensive changes in the earlier concepts of the nonglacial deposits, particularly in southwestern Kansas, in other regions it has not been adequate to define clearly the major problems.

SUBSURFACE GEOLOGY OF THE GULF COASTAL PLAIN IN SOUTHEASTERN MISSOURI

BY JOHN G. GROHSKOPF

Subsurface information for the area is scanty, but samples of cuttings from several deep wells yield information regarding the general structure and stratigraphy. The regional dip is to the southeast of the Ozark uplift and averages about 40 feet to the mile. The thickness of the Cenozoic and Mesozoic sediments ranges from a few feet in the outcrop to more than 2700 feet in the extreme southeast county of the area. It is possible to delineate in the subsurface the various outcropping units. Normally the Cretaceous rests on successively younger Ordovician rocks downdip and away from the Ozark uplift. This, however, is not the case in Pemiscot and New Madrid counties, where the Cretaceous rests on Cambrian dolomites. This indicates a period of uplift and erosion which in Missouri can only be dated as pre-Cretaceous.

In this area two wells have been drilled through the Bonneterre. These wells bottomed in quartzite which may be equivalent to the LaMotte sandstone. In New Madrid County the Bonneterre is over 1600 feet thick, more than three times the average thickness found in Missouri outside the Coastal Plain region. The lithology of the Bonneterre also changes from crystalline dolomite to dolomitic shale in the upper portion, while the lower few hundred feet are a white crystalline glauconitic limestone.

GLASS SANDS OF THE ARBUCKLE MOUNTAINS, OKLAHOMA

BY WILLIAM E. HAM

The worked glass sand beds in the Arbuckle Mountains, 150 to 400 feet thick, are in the Ordovician McLish and Oil Creek formations (Simpson group), which crop out over a wide area with comparatively flat surface.

Quarries are open pits 30–70 feet deep, with 3–10 feet of sandy soil overburden. The sand is white, massive-bedded, and loosely consolidated; it is quarried by hydraulicking and beneficiated by washing, which removes clay and scours off coatings of iron oxide (limonite). One company, however, uses tabling and flotation to reject pyrite.

Plant run sand is of fine size, 87 per cent between 60 and 170 mesh, and averages about 99.8 per cent SiO_2, 0.035 per cent Fe_2O_3, and 0.07 per cent Al_2O_3. Four plants currently produce about 60 cars (3000 tons) per week, valued at about $2.00 per ton; nearly all of it is shipped to glass plants in Oklahoma and Texas. Enormous reserves are available in the district.

NORTHEASTERN OZARK EARTHQUAKES

BY ROSS R. HEINRICH

In recent years instrumentally determined epicenters of five earthquakes have been located on the northeastern flank of the Ozark Uplift. The local distribution of these epicenters shows: (1) the dangers of considering northeastern Ozark seismic activity as arising from geographically delineated seismic districts, and (2) the importance of discussing the earthquakes in relation to the zone of faults and flexures which lies between the Ozark Dome and other major tectonic features to the north and east. Interesting structural features are found in the vicinity of the epicenters of individual earthquakes. The epicenters were situated: (1) on the limb of the Eureka, Missouri, anticline, (2) adjacent to the faulted Waterloo-Dupo, Illinois, anticline, (3) in the Ste. Genevieve, Missouri, fault zone, (4) in the vicinity of the Moselle, Missouri, fault, and (5) in the large faulted block southwest of the magnetic high near Bourbon, Missouri. Depth of foci of at least 5 miles is indicated by the distribution of felt intensities and the character of the seismograms. In this connection the possible shielding effect of the Ozark core invites further study.

SOME PLEISTOCENE PROBLEMS IN MISSOURI

BY CHAUNCEY D. HOLMES

Iowa and northern Missouri together form a natural unit of glaciated territory between the Missouri and Mississippi rivers. While Iowa has become known as a classic area for North American Pleistocene history, the regional record is incomplete without an equally intensive study of glaciation in Missouri. The latter area presents some of the drift-border phenomena to which the Nebraskan and Kansan drifts are related.

Relation of drift to underlying bedrock has been studied in northwest Missouri, and published maps suggest somewhat greater subdrift relief in that area than in adjacent parts of Iowa. More detailed data are needed to evaluate the nature and amount of glacial erosion (if any) in the region. No studies bearing on that problem have been reported from northeast Missouri.

Additional criteria are needed for distinguishing between the Nebraskan and Kansan drifts, and refinements in drift-boundary mapping should be made. In this problem the till-fabric technique may hold much promise, especially if contrasting local and regional patterns of ice movement should be discovered.

Problems of drift-limit mapping and of the age relations of till outliers involve also the history of known erratics far beyond the apparent drift limits. Evaluation of evidence should distinguish clearly between drift limit and possible glacial limit.

Evidence as to periglacial conditions as well as to interglacial climates should be looked for south of the glaciated area.

IGNEOUS METAMORPHISM IN THE OROFINO REGION, IDAHO

BY CLAYTON H. JOHNSON

The purpose of this investigation was to determine the nature and origin of the complex, hornblende-rich, gneissic rocks in the contact-metamorphic zone of the Idaho batholith where exposed in the lower Clearwater River Canyon west of Orofino, Idaho. It was thought that these rocks might differ somewhat in character and origin from previously described granitized sediments. A critical microscopic comparison of these rocks with the recognized gneisses formed by granitization in other parts of the region was made to obtain a better insight into their origin.

The Orofino region is underlain by a thick, complex series of sedimentary rocks, which were metamorphosed across a broad zone by the intrusion of the Idaho batholith. After the intrusion of the batholith, erosion cut deeply into the metasediments and exposed a large area of the batholith. During the Miocene both the metasediments and the batholith were covered by the Columbia River basalt flows.

The metasedimentary rocks have the composition and the textural appearance of igneous rocks. However, microscopic study indicates that the present composition and the texture of the rocks are the result of the hydrothermal metamorphism of siliceous sediments. Because the metasedimentary rocks have the composition of igneous rocks, they have been given igneous rock names. These are hornblende-quartz diorite gneiss, hornblendite, biotite-quartz diorite gneiss, and granodiorite. All these rocks are gradational into one another and have been separated on the basis of thin-section study.

NATURAL STEAM AT LARDERELLO, ITALY

BY W. D. KELLER AND ADRIANO VALDUGA

The natural steam (vents, soffioni) of the Larderello and adjacent regions in Tuscany, Italy, was used in the largest pre-war natural steam power plant installation in the world. The boric acid and other mineralizers in the steam were exploited in a large chemical industry. Many wells were drilled to tap the emanations delivered through fractures from a probable batholith freezing beneath.

Pneumatolysis is at work on a grand scale. This geologic occurrence merits more attention from American (and European) geologists than it has received. Data collected on brief field visits during early partial rehabilitation of the plants following bombing and demolition are presented.

POST-CAMBRIAN IGNEOUS ACTIVITY IN SOUTHEASTERN MISSOURI

BY ALBERT L. KIDWELL

Igneous dikes and pipes, some of which have been called diatremes, occur in the Cambrian sedimentary rocks throughout an area of at least 75 square miles in southwestern Ste. Genevieve County and southeastern St. Francois County, Missouri. Seventy seven of these occurrences have been reported, and the majority of them were studied in this investigation.

Two types of material are present in the igneous occurrences: ultrabasic igneous rock; and inclusions consisting of granite, sandstone, dolomite, limestone, and chert. Three kinds of intrusions have been recognized in the area: (1) ultrabasic igneous rock with few inclusions, (2) sedimentary and igneous inclusions in an ultrabasic matrix, and (3) sedimentary blocks with a small amount of carbonate and highly altered ultrabasic matrix.

The igneous rocks cut sedimentary formations from the Lamotte sandstone to the Potosi formation. They crop out at variable elevations over a vertical range of at least 400 feet. The age of the igneous activity was formerly called post-Devonian on the basis of Devonian fossils in inclusions in the diatremes. During the present investigation inclusions of fossiliferous limestone were found which are believed to be Mississippian in age.

Magnetometer surveys run over representatives of each kind of intrusion showed them all to be more highly magnetic than the surrounding sedimentary rocks.

These Missouri occurrences have been compared to similar types in adjoining States, and it is

concluded that they are all of approximately the same age and origin. Possible relationships with the ore deposits of the Mississippi Valley are mentioned.

CORRELATION OF ILLINOIS COAL BEDS BY PLANT MICROFOSSILS WITH REMARKS ON INTERREGIONAL CORRELATIONS*

BY R. M. KOSANKE

An intensive study of the fossil microspores, isospores, and prepollen isolated from Illinois coal beds has shown numerous genera and species to be present. Many of these are characteristic of various coal beds and in certain cases restricted to one or more benches of individual beds.

Some correlations have proven of considerable interest due to lateral variations in the abundance of certain genera and species. Important in this class are No. 6 and No. 5 coal beds because they were deposited over wide areas, and abundance variations may be of considerable ecological significance.

Certain attempted correlations of coal beds at approximately the same stratigraphic position revealed that no correlation could be made. Examples of this would be the Battery Rock coal with the Babylon coal, and the La Salle coal (coal below La Salle limestone in the type area) with the Shoal Creek coal (coal below the Shoal Creek limestone at the type locality). It appears that the Babylon coal is younger than the Battery Rock coal, and the La Salle coal is younger than the Shoal Creek coal.

Experiments with specific interregional correlations have demonstrated a wide lateral distribution of plant microfossils necessary for correlations of this nature. There is a similarity between the Middle Kittanning coal bed of Ohio with the No. 6 coal bed of Illinois, but specific interregional correlations should not be attempted until sufficient data are accumulated in both regions of attempted correlations, and if possible between these regions. Microfloral zones have been recognized in Illinois which could be used interregionally until sufficient information warrants specific interregional correlations.

PHYSIOGRAPHIC DIVISIONS OF ILLINOIS

BY M. M. LEIGHTON, GEORGE E. EKBLAW AND LELAND HORBERG

The classification proposes minor modifications in Fenneman's divisions and recognizes subdivisions of the Till Plains and Great Lakes section, based largely on glacial features as follows:

Central Lowland province
- Till Plains section
  - Bloomington Ridged Plain
  - Kankakee Plain
  - Green River Lowland
  - Rock River Hill Country
  - Galesburg Dissected Upland Plain
  - Springfield Plain
  - Mt. Vernon Hill Country
- Great Lake section
  - Chicago Lake Plain
- Wisconsin Driftless section

Ozark Plateaus province
- Lincoln Hills section
- Salem Plateau section

Interior Low Plateaus province
- Shawnee Hills section

Coastal Plains province
- East Gulf Coastal Plain
- Mississippi Alluvial Plain

The boundaries and characteristic features of the subdivisions are described, and their origin and relations to glacial features and bedrock topography are discussed.

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STRUCTURAL DETERMINANTS IN APPALACHIAN DRAINAGE

BY H. A. MEYERHOFF AND E. W. OLMSTED

The theory of regional superposition, advanced by Douglas Johnson and his students as an explanation for the behavior of Appalachian streams, utilizes a coastal plain of regional extent as a means of superposing streams upon resistant ridges. Re-examination of stream courses shows that all instances of superposition are genetically related to (1) broad features of Appalachian structure and Paleozoic stratigraphy; (2) local structures; (3) Triassic sedimentation and structure; and (4) marginal marine overlap of Miocene rather than Cretaceous age. Nittany arch, if restored, is shown to have been not less than 3000 feet higher than Kittatinny arch, hence drainage could not have flowe din any direction except southeast in post-Permian time. Susquehanna River and its tributaries utilize every structural detail on the southeastern slope of this anticlinorial structure with such fidelity as to preclude regional superposition. The Adirondack dome played a comparable role in determining the course of the Delaware. Further, study of the Cretaceous coastal plain contact shows that the pre-coastal plain surface—the Fall Zone "peneplane"—was rugged and that the "Cretaceous peneplane" is a myth. The distribution of Triassic and Cretaceous-Eocene sediments leaves little doubt about the uninterrupted southeastward orientation of post-Paleozoic drainage and establishes Appalachian orogeny and Triassic diastrophism as the determinants of major drainage lines on the Atlantic Slope.

INDUSTRIAL DOLOMITE AND LIMESTONE IN OKLAHOMA

BY MALCOLM C. OAKES AND WILLIAM E. HAM

The exceptionally pure dolomites of Oklahoma are chiefly in the Arbuckle Mountains, principally in the Royer formation (Cambrian) which is 550 feet thick. Similar dolomites are found in the Wichita Mountains. The St. Clair limestone (Silurian) of Sequoyah County contains large workable reserves of high calcium limestone of superior quality, and stone nearly as good is available in large quantities from the Fernvale (Ordovician) and Wapanucka (Pennsylvanian) limestones of the Arbuckle Mountains. There are several large deposits of siliceous dolomite suitable for making rock wool of high quality.

Deposits of all these materials are well situated with regard to fuel and transportation.

SUBMERGENCE AS A CAUSE OF SHIFTING STREAM DIVIDES

BY E. W. OLMSTED

Studies in New England suggest that times of marginal marine overlap are periods of shifting stream divides. Longitudinal profiles of all streams in the first cycle are similar when grade is attained. Following submergence, the gradient is no longer adjusted to volume, load, and length. In the shortened stream, processes of adjustment are transmitted headward more rapidly than formerly. Aggradation occurs in the lower portion, but the headward section is now too steep in relation to the lower stretches, hence downcutting to a flatter curve ensues. The steep component of the gradient is forced to move headward, thus shifting the divide and facilitating stream capture.

However, divide migration would be precluded if the sea overlapped opposite sides of a divide area, or if small streams were shortened to a point where the steeper headwater portion would now have just the component of declivity necessary to transport their loads with the smaller volume.

Uplift is a less likely cause of shifting divides because of the increase in the length of the stream gradients.

Thus it is concluded that divides once established tend to persist through long periods of time if continents are undergoing positive epeirogenesis. Negative movements such as occurred along the Atlantic slope of the United States in the Cretaceous and which continued in the Tertiary (except the

Oligocene) should be reflected in the hinterland by features of stream capture and shifting of long-established divides. The evidence available indicates that this is the case.

MARINE PLANATION IN SOUTHERN NEW ENGLAND

BY E. W. OLMSTED AND L. S. LITTLE

An abrupt topographic break may be traced by a rise in elevation on the interstream ridges from Sparkill Gap in the Palisades across southeastern New York, southern Connecticut, into western Rhode Island. The sharp break which faces Long Island Sound occurs just above the 600-foot contour interval. It crosses various types of schist, gneiss, and Triassic trap. The surface below 600 feet consists of a series of benches which slope gently seaward and step down toward Long Island Sound. Below 600 feet youthful topography with smooth, flat-topped ridges of uniform elevation abuts mature country with irregular, rounded hilltops. The two surfaces are commonly separated by a depression.

In the northern section, the streams flow in various compass directions controlled by weak rock elements—*e.g.*, the limestone underlying the Croton and Still rivers. Southward, the drainage ignores the underlying structure and flows directly to Long Island Sound. Many small streams head within this area.

The bevelled character of the coastal margin, which abuts irregular country inland, is interpreted as a surface of marine origin. The rise in elevation marks the position of the shore line which is tentatively dated as Miocene. This marine overlap accounts for the features of marginal superposition in southern New England such as the course of Connecticut River below Middletown. The irregularity in trend of this shore line indicates that the marine cycle was interrupted when still in the youthful stage.

The former shore line provides a convenient boundary for the "Seaboard Lowland Section" in southern New England.

RECENT STUDIES OF THE PLATTIN FORMATION IN MISSOURI

BY TRUSTEN E. PEERY

A detailed study of Plattin paleontology and stratigraphy was begun last November. Recent collections of Plattin fossils have been made available, and many new collecting localities have been visited. When the present study is complete the known fauna of the Plattin will be considerably enlarged, and the stratigraphic units and distribution of the formation more adequately described.

HEAVY MINERALS OF THE BEACH SANDS OF FLORIDA

BY WILLARD B. PHELPS

The beach and dune sands of Florida contain the heavy minerals ilmenite, rutile, and zircon, which are important for their titanium and zirconium content. There are two companies now recovering these minerals from the sands on the east coast. Other heavy minerals are found in minor quantities, such as garnet, staurolite, monazite, epidote, kyanite, and tourmaline. The best natural concentrates of these minerals are found in four general regions, namely, the Jacksonville and Indian River districts on the east coast, the Venice district on the west coast, and the coastal area of northwestern Florida.

The deposits are generally located in definite layers or lenses in the dunes behind the beach and in local concentrations on the beaches now bordering the coast. The most abundant heavy mineral is ilmenite, usually followed by rutile and zircon, respectively. The size of the heavy minerals varies from .246 millimeter in diameter in the Indian River district to less than .074 millimeter in the Jacksonville district. The percentage of heavy minerals and size distribution have been determined for 25 representative localities in Florida.

STRATIGRAPHY OF THE PENNSYLVANIAN OF CENTRAL TEXAS WITH SPECIAL REFERENCE TO THE LLANO REGION

BY F. B. PLUMMER

The Lower Pennsylvanian section of north-central Texas consists of the following groups: Mineral Wells, Millsap Lake, Smithwick, and Marble Falls. The stratigraphic positions of these lower groups in terms of Appalachian and Midcontinent nomenclature are as follows:

Texas			Midcontinent	Appalachians
Series	Group	Formation	Series	Series
Strawn	Mineral Wells	Numerous formations	DesMoines	Allegheny
	Millsap Lake			
Bend	Smithwick	Undifferentiated	Bend or Lampasas	Pottsville
	Marble Falls	Big Saline		
Morrow		Sloan	Morrow	

The continuous dashed lines represent a major unconformity, the shorter dashed lines represent a minor unconformity.

Each group has a characteristic fauna, characteristic lithology, and in most cases the groups are separated by distinct unconformities marked by characteristic basal conglomerates. Each group is described in some detail, its characteristic fossils illustrated, its subdivisions indicated by charts and brief descriptions, and criteria for identifying and correlating the chief subdivisions described in as much detail as space and time permit.

CEMENT ROCK AND LIMESTONE RESOURCES OF NORTH DAKOTA*

BY WILLIAM E. POWERS

A natural cement rock is furnished by the Niobrara shale formation, which crops out in the escarpment near the Pembina-Cavalier county boundary known locally as the "Pembina Mountains." The rock is a gray calcareous shale containing from 45 to 75 per cent calcium carbonate. The exposed thickness ranges up to 60 feet or more, but the formation is heavily overlain by Pierre shale in most places. Prior to 1910, a cement plant was operated near the village of Concrete. The average Niobrara is too low in lime to produce a standard Portland cement. No local source of lime carbonate is available save very limited spring deposits of calcareous tufa. It is believed that, with the addition of limestone, a very satisfactory Portland cement could be made from the Niobrara.

Limestone deposits of good grade for lime occur near Lefor in southern Stark County and thence southeast into northern Hettinger County, to Colgrove and Bull buttes. Smaller deposits occur in Young Mans, Antelope, and a larger associated bu*te in eastern Stark County. The limestone occurs in horizontal layers from 6 inches to 2 feet thick, interstratified with marly clay, in a unit 10 to 25 feet thick that caps the buttes mentioned. In the largest deposit, Colgrove Butte, the average total thickness of exposed limestone beds is 2 feet. The very little silica present occurs mainly as small silicified gastropods. This stone has been used to only a small extent for lime and as building stone. The reserves are considerable, but save for the deposits at Antelope Butte are all 15 to 20 miles from a railroad.

* With the permission of the State Geologist of North Dakota.

KILMICHAEL DOME, AN UNUSUAL UPLIFT IN NORTH-CENTRAL MISSISSIPPI

BY R. R. PRIDDY

Kilmichael Dome is a sharp uplift in the hilly section of north-central Mississippi, on the east limb of the Mississippi Embayment where strata normally dip gently west. The dome is hat-shaped. A central uplift of some 1200 feet 3 to 5 miles across represents the crown, a narrow graben completely encircling the uplift represents the brim, and a low horst detected beyond the graben on the downdip side represents an upturned edge of the brim. All surface beds involved are Eocene. Wilcox strata form the uplift, Claiborne beds form the graben, and both units form the horst, but they are all so poorly consolidated and of such low and nearly uniform resistance to weathering that there is no topographic evidence of structure. An oil test drilled near the center was dry but showed thickened and faulted Cretaceous and Commanchean sediments overlying slightly metamorphosed Pennsylvanian shales. In some shallow fault planes this test and near-by core holes are reported to have had gravels similar to Pliocene or Pleistocene gravels preserved locally on the surface, thus dating the movement.

PENNSYLVANIAN FLORAL ZONES AND PROVINCES*

BY CHARLES B. READ

Remains of plants are widespread in strata of Pennsylvanian age in both North America and South America where they are useful in problems of intraregional and interregional correlation. In both North America and South America floras of the Pennsylvanian epoch are recognized as belonging to two distinct floral areas—the Arcto-Carboniferous and the Antarcto-Carboniferous provinces. Within each of these there is local floral differentiation that is inferred to have resulted from variation of environments.

The Arcto-Carboniferous province is characterized by eight floral zones during the Pennsylvanian epoch. From oldest to youngest these are the zones of (1) *Neuropteris pocahontas* and *Mariopteris eremopteroides*, (2) *Mariopteris pottsvillea* and *Aneimites* spp., (3) *Mariopteris pygmaea*, (4) *Cannophyllites* spp. and *Neuropteris tenuifolia*, (5) *Neuropteris rarinervis*, (6) *Neuropteris flexuosa* and abundant *Pecopteris* spp., (7) *Lescuropteris* spp., and (8) *Odontopteris* spp. and *Danaeites* spp. The zone of appearance of *Calipteris conferta* characterizes the superjacent Permian(?) rocks. Although these index fossils and their associates provide a practical basis for age differentiation of rocks of "coal measures" facies it must be borne in mind that there is geographic variation in the assemblages. Local elements are very common in Pennsylvanian strata of the "Ancestral Rocky Mountain" region; their presence is explained by persistence of upland environments adjacent to sites of deposition.

Strata of Upper Carboniferous or Pennsylvanian age in portions of South America are characterized by Antarcto-Carboniferous sequences of plants. Floral zones that have been recognized on the basis of available data are (1) a lower zone of *Gangamopteris* spp., *Glossopteris* spp., and *Phyllotheca* spp., and (2) an upper zone characterized by mingled Antarcto- and Arcto-Carboniferous elements. Available collections do not permit further differentiation on a sound basis. However, variation in the Arcto-Carboniferous content may provide a means for closer zonation.

DISTRIBUTION AND CORRELATION OF PENNSYLVANIAN ROCKS IN LATE PALEOZOIC SEDIMENTARY BASINS OF NORTHERN NEW MEXICO†

BY CHARLES B. READ AND GORDON H. WOOD

Pennsylvanian rock sequences in the Sangre de Cristo, Sandia, Manzano, Los Pinos, Oscura, Nacimiento, and San Pedro mountains, the Lucero and Zuni uplifts, and in the San Juan, Rowe-Mora, and Las Vegas basins are shown in several series of graphic sections. Thickness and facies maps accompanying the stratigraphic diagrams summarize the variations.

The early Pennsylvanian deposits were transgressive sandstones and shales succeeded by marine limestones. Deposits of this transgression are widespread, and they were locally modified and restricted in the northern part of New Mexico by the development of early positive axes and troughs

* Published with the permission of the Director, United States Department of the Interior, Geological Survey.
† Published with the permission of the Director, United States Department of the Interior, Geological Survey.

of the "Ancestral Rocky Mountains." Later these axes and troughs became more extensive and pronounced in northern New Mexico. Sedimentation was under geosynclinal or trough conditions characterized by rapid facies changes during the final stages of Pennsylvanian as well as Permian(?) deposition.

Sedimentation was more uniform in those portions of New Mexico west of the "Ancestral Rocky Mountains." Positive elements such as the Zuni and Defiance uplifts were only slightly affected by the strong medial and late Pennsylvanian orogeny that occurred farther east.

The Pennsylvanian sequences of New Mexico present interesting problems of intra- and interregional correlation. Many of the difficulties encountered are those that may be expected in areas of rapid facies change.

PLEISTOCENE SEDIMENTS OF THE ST. LOUIS AREA

BY PERCIVAL ROBERTSON

A striking example of ice rafting of a mass of boulder clay from the Wisconsin ice front to the vicinity of St. Louis is described.

The Illinoian ice sheet crossed the Mississippi at St. Louis leaving a terminal moraine. This ice and the moraine dammed the Mississippi forming a lake somewhat similar to former Lake Calvin in Iowa. The relationship of the lake terraces and the terminal moraine is discussed.

Older glacial drift in this vicinity, higher terraces, and more ice-rafted boulders are described and their possible interrelationship discussed. The suggestion is made that certain glacial phenomena previously described south of the Missouri River, and usually mapped as Nebraskan in age, could be as simply explained as ice-rafted Kansan boulders. The evidence supporting this hypothesis includes some characteristics of the drift in St. Louis, terrace elevations, and the elevation of boulders found south of the Missouri River.

SOME STAGES IN THE POST-TRIASSIC DEVELOPMENT OF THE NEW JERSEY PIEDMONT AND COASTAL PLAIN

BY W. T. THOM, JR., AND MEREDITH E. JOHNSON

An analysis of detailed surface and subsurface evidence from areas within and adjacent to the New Jersey Piedmont and Coastal Plain provinces indicates that the Post-Triassic history of these regions is divisible into several evolutionary phases or stages, about as follows:

Stage 1. Post-Triassic and pre-Lower Cretaceous (= Jurassic) development of widespread system of gravel-coated truncation—plains or "bench surfaces" like those developed during Tertiary time in parts of the Great Plains and Rocky Mountain regions.

Stage 2. Late Jurassic (?) uplift, causing the cutting of deep narrow valleys, by southeastward-flowing streams, plus the redevelopment of strike ridges and trellis-drainage systems at least as far southeast as the present Delaware Valley-Atlantic Ocean divide.

Stage 3. Lower Cretaceous downtilting, with the late Jurassic stream courses being back-filled by gravels and arkose stripped from the newly uptilted portions of the Jurassic gravel-plain areas.

Stage 4. Recurrent and progressive depression of large parts of the Coastal Plain and Piedmont during most of Lower Cretaceous to Upper Miocene time, with further back-filling of the Jurassic valleys (and burial of the Jurassic bench-surfaces).

Stage 5. Gradual and recurrent uplift and tilting of both the Coastal Plain and Piedmont areas during post-Miocene, pre-Bridgeton, pre-Pensauken, and pre-Cape May times, coupled with (a) the further compaction of the sedimentary fills within the pre-Lower Cretaceous valleys and gorges—leading to the reproduction of pre-Cretaceous drainage patterns by Quaternary water courses within the Coastal Plain region, and (b) the resurrection, re-excavation and reoccupation of some pre-Cretaceous water gaps and gorgelike valleys by modern streams of the Piedmont of New Jersey and southeastern Pennsylvania.

GLACIAL SLUICEWAYS AND LACUSTRINE PLAINS OF SOUTHERN INDIANA

BY WILLIAM D. THORNBURY

Lacustrine plains of two distinct ages and origins occur in southern Indiana. One system of lakes of Illinoian age was formed along the ice front due to ponding of the southwestward-flowing drainage.

Lakes of this origin developed along the margin of the Illinoian lobe which extended into southwestern Indiana but not along the lobe in southeastern Indiana since there the drainage was away from the ice front.

Another and much more extensive system of glacial lakes developed during Wisconsin time, south of the Shelbyville moraine, due to the ponding of tributary valleys by extensive valley trains built down those streams which acted as sluiceways for Wisconsin melt waters. Lacustrine plains of this origin are extensively developed in the tributaries of the Wabash, Ohio, and White rivers. The elevations of the lacustrine plains in successive tributaries decrease downstream in accordance with the slopes of the valley trains in the major valleys.

The Wisconsin lacustrine deposits are composed of calcareous clays and silts which frequently show a degree of lamination approaching that of glacial varves. Calcareous concretions are particularly abundant in the deposits adjacent to the sluiceway which carried highly calcareous melt waters.

Associated with the valley trains and lacustrine plains, particularly along the lower Wabash and Ohio valleys, are areas of dune sand and loess. The dunes are largely restricted to the sluiceways, but the loess mantles the uplands between adjacent lacustrine flats.

PLEISTOCENE PROBLEMS IN IOWA

BY A. C. TROWBRIDGE

As a result of the work and publications of the late Dr. George F. Kay and his assistants, the Pleistocene geology of Iowa is well in hand. However, there remain some problems to be solved.

The known Loveland gravel, sand, and loess began to be deposited after valleys had been developed in the Kansan gumbotil surface and are therefore not older than late Yarmouth. They are covered in some places by Iowan till and in many places by only slightly younger Peorian loess. It remains to be determined whether the formation is all post-Illinoian or whether part of it may be older than the Illinoian.

The Peorian loess may contain two loesses, one of which is of medial or late Wisconsin age.

There is evidence in Iowa that the "deep stage" in the excavation of the Mississippi River valley is post-Kansan, but Horberg has presented evidence that buried valleys of this same type in Illinois and apparently continuations of the Mississippi River valley near Clinton, Iowa, are pre-Kansan if not pre-Nebraskan. This problem has not been solved to date, but some progress is represented by its recognition and by review of the evidences on both sides.

Evidence is presented that there is really early Wisconsin Iowan till and glacio-fluvial material in eastern Iowa from which most or all of the Peorian loess was derived and that these deposits are not merely Mankato outwash and late Wisconsin loess as contended by Hobbs.

PROJECTED CLIMATIC ATLAS OF THE UNITED STATES

BY S. S. VISHER

The considerable interest aroused by the publication during recent years in leading geological, ecological, geographical, meteorological, and general scientific journals of more than 150 climatic maps of the United States has encouraged the preparation of an atlas containing these and numerous other climatic maps of possible utility. A large share of these maps are based on recently published official maps; others on significant nonofficial published maps; the remainder are new, based upon data recently available. A total of more than 500 maps have already been prepared. The special object of this paper is to solicit co-operation in the effort to include all maps, based on adequate data, that would be of considerable utility. Those who know of good maps which might have escaped the compiler are asked to report them.

The projected atlas at present has 40 maps on average annual, seasonal, and monthly temperatures, 52 on the average daily means for each week in the year, 52 on the average daily maximum and minimum temperatures of every other week, 38 on temperature seasons, 21 on killing frosts and the length of the growing season, 32 on contrasts in house-heating requirements, 76 on relatively high and relatively low temperatures, 44 on temperature ranges and sudden changes, 55 on winds, 22 on

sunshine, 36 on humidity and evaporation, 172 on normal precipitation, 202 on precipitation variability, and 40 on climatic regions and changes.

REGIONAL VARIATIONS IN PENNSYLVANIAN LITHOLOGY

BY HAROLD R. WANLESS

The Pennsylvanian system in the United States includes nearly all the common types of sedimentary rocks. At most localities the column consists of a more or less regular repetition of similar successions of rock types recording depositional cycles. These successions, which have been called cyclothems in the eastern and central United States, vary in character and in the proportion of marine, brackish, and nonmarine sediment throughout the United States. Patterns of variation of cyclic successions and regional variations in the prominence of various sedimentary types are discussed, and graphic methods of displaying regional lithologic variations are described. The relation between thickness, lithology, fossil content, and resources of coal and petroleum are considered.

INVERTEBRATES IN PENNSYLVANIAN CORRELATIONS

BY J. MARVIN WELLER

Comparatively few Pennsylvanian fossils are known to have precise zonal significance, and consequently most species at present have no more than general correlative value. This is partly because the Pennsylvanian stratigraphic sequence is uninterrupted by important breaks separating easily distinguished faunas except locally, and partly because most Pennsylvanian species are too poorly understood to be recognized with precision and separated from closely related forms. Complications are introduced by the extreme diversity of Pennsylvanian environments which resulted in the close stratigraphic association of almost wholly different faunules.

The faunal approach to Pennsylvanian correlation has produced results unsatisfactory except in a most general way. Detailed correlations can be made much more accurately on the basis of lithologic sequence, and studies of this type have revealed notable errors in correlations based on fossils. Moreover, faunal studies have resulted in the misidentification of certain diagnostic species and confusion regarding the ranges of others.

The detailed study of closely related fossils from many different stratigraphic zones, in an effort to work out evolutionary trends, gives great promise of much more useful and significant results. The establishment of sequences of evolutionary stages is now known to be possible and offers a means of correlation far superior to that which is dependent on the mere presence or absence of individual index species. All such studies are still in their preliminary stages but progress has been made with several groups, particularly the fusulinids.

ABSTRACTS OF PAPERS PRESENTED AT MEETING OF SECTION E, A.A.A.S.

Cambridge, Massachusetts, Meeting, December 30 and 31, 1946

TRAINING THE GEOLOGIST FOR GEOPHYSICAL WORK

BY JOHN N. ADKINS

It seems essential that the training of a modern geologist include study in applied geophysics. However, in many cases the geology student is unable to profit from courses in geophysics because he has had insufficient training in fundamental mathematics and physics. This need must be anticipated early and it is not easy to require more course work of a student who already has a crowded schedule. Nevertheless, it is recommended strongly that a reasonable amount of work in mathematics and physics be included in the undergraduate training in geology.

AREAL MAPPING PROGRAM IN NEW HAMPSHIRE

BY MARLAND P. BILLINGS

As a result of the present areal mapping program in New Hampshire, which began in 1931, colored geological quadrangle maps on a scale of 1 inch to the mile have been published for 25 per cent of the State. Maps covering an additional 12 per cent of the State are ready for publication. Field work is in progress in 15 per cent of the State. Within 2 years, therefore, maps covering 52 per cent of the State on the inch to a mile scale should be published or ready to publish.

Originally there was no organized plan to map the whole State or even a large part of it. But because of a number of fortuitous circumstances a program evolved over a period of years; geologists became interested in New Hampshire, professors at Dartmouth College and the University of New Hampshire energetically supported the publication program, and several high State officials recognized the value of the studies.

In a sense, the geological maps are a by-product of the study of the stratigraphy, structure, metamorphism, and petrology; the preparation of maps is a necessary part of such an investigation, but to the geologist the maps are not an end in themselves. Our investigations have been confined to bedrock geology, because Professor Goldthwait had already initiated a study of the glacial geology. Moreover, the economic aspect of the geology has not been adequately considered in this program, the principle objective of which has been to understand the basic geology of the region.

SOME MAJOR PROBLEMS OF NEW ENGLAND GEOLOGY

BY MARLAND P. BILLINGS

The problems of New England Geology, although many and difficult, are not insurmountable. Perhaps the foremost problem in the bedrock geology, and one that must be solved first, is the stratigraphy, age, and structure of the sedimentary and metamorphic rocks. The principle of metamorphic zoning is an important tool.

Another major problem is the age of the folding. Many suggestions have been made, but few tangible pieces of evidence have been presented. The idea that the orogeny in western New England is Taconic is based on data of doubtful validity. Although the folding in New Hampshire appears to be Acadian, there is some contradictory evidence. The folding in southeastern New England is undoubtedly Appalachian.

Associated with the problem of orogeny is the question of magmatic cycles, both intrusive and extrusive. At least six cycles of intrusive igneous activity may be recognized, ranging from pre-Cambrian to Permian. Siliceous and mafic rocks appear to have been extruded during much of the Paleozoic.

There is no agreement on the physiographic development of New England. We are still uncertain about the number and age of the erosion surfaces, and some investigators believe that some of them may be marine terraces rather than surfaces of subaerial denudation. Although most geologists grant that New England was probably invaded by continental ice sheets during each of the four stages of the Pleistocene, the evidence bearing on this problem is scanty.

How shall we attack these problems? The main offensive must be mounted by the infantry, the

field geologist who patiently plods around on foot. Airplanes and seismology will provide support, but in a terrain such as New England they alone cannot win the struggle. Areal mapping is the solution to our problem. The discovery of new fossil localities will provide key horizons that are sorely needed. More lead-uranium ratios of pegmatite minerals should be determined. Geophysical studies will provide valuable data, particularly concerning the nature of the crust beneath the visible rocks. Laboratory studies of scale models and artificial melts will provide important clues. But all these studies will yield little if they are not tied to the field geology.

PETROLOGY OF THE CORE OF THE BLUE RIDGE IN CENTRAL VIRGINIA

BY ROBERT O. BLOOMER

The core of the Blue Ridge in the vicinity of James River is formed of the rock classified as hypersthene granodiorite on the geological map of Virginia. Detailed studies of this rock mass in central Virginia disclose two structural and seven mineralogical phases. There is a marked variation in mineral composition that can hardly be attributed to magmatic segregation. There are furthermore two generations of feldspar and quartz. The core rock has consequently been classified as migmatite. It was probably formed as an aureole or granitized zone on the periphery of a batholithic body of granitic rock subjacent to or injected into the Lovingston quartz monzonite gneiss. The Lovingston gneiss forms a large batholithic mass in the boundary zone between the Blue Ridge and Piedmont provinces in central Virginia.

SINGLE CRYSTALS OF SOME MAGNETIC METALS

BY R. M. BOZORTH

Single crystals of a number of metals have been formed by slow cooling of the melt, as previously described (Cioffi and Boothby, 1939). These include the elements nickel and cobalt, and alloys of iron-nickel, iron-silicon, nickel-copper, iron-cobalt-nickel, and iron-nickel-molybdenum. Materials of high purity were melted in an atmosphere of purified hydrogen, in an alumina boat free from additions of silica. Cooling through the melting point was 1° to 10° C. per hour. Occasionally the whole ingot was a single crystal weighing about a pound. Crystal orientations were determined provisionally by reflection of light from etch pits, and finally by X-rays. Specimens were prepared for measurements of magnetic properties. Ferromagnetic anisotropy (H. J. Williams, 1937; Williams and Bozorth, 1939; Bozorth, 1937) has been studied by cutting hollow parallelograms with each side parallel to a crystallographic direction of the form <hkl>, with hkl equal to 100, 110 or 111 in different specimens. Powder-patterns, made (Williams, 1946) by deposition of colloidal Fe_3O_4 on various crystallographic planes, are of great variety and show how the magnetic-domain structure depends on magnetization and on crystallographic orientation.

MAP PROJECTION DEMONSTRATION APPARATUS

BY ROBERT F. COLLINS

The instrument demonstrates by projected light rays the geometric modes of cylindrical, conic, and azimuthal classes of map projections. It is a teaching tool for projections of spherical segments on developable surfaces.

The base of the instrument is a brass cylinder 6 inches in diameter, 8 inches high on a wood base. Its upper rim carries a brass ring graduated to 180° which is the bearing surface for the two interchangeable hemispheres. The latter are made of brass wire meridians and parallels, one with the pole at zenith, the other with poles at the rim. Inside the base cylinder a single-filament auto headlight bulb is mounted on a swinging arm to allow shifting the nearly point-light source from the center of the sphere to the lower pole by a half turn of a knob.

Two brass arms are affixed to the sides of the cylinder to support the interchangeable screens. The bearings for the screens are in the plane of the hemisphere base and are graduated through 270°. The three screens are (1) translucent plastic half cylinder 16 inches long and 8½ inches diameter, (2) frosted plastic 45-degree cone 20 inches diameter at base, and (3) ground glass plate 24 inches square. Any screen can be made tangent to any part of the hemisphere and adjusted to gnomonic or stereographic projection in 5 seconds.

MASSACHUSETTS COOPERATIVE GEOLOGIC PROGRAM*

BY L. W. CURRIER

In July 1938 a long-range program for geologic investigations and mapping in Massachusetts was started under a co-operative agreement between the Massachusetts Department of Public Works and the United States Geological Survey. The objective is a new and detailed geologic map of the State. Incidental to this program, but an essential part of it, are the furnishing of geologic data as needed by the engineers of the Department of Public Works, the recording and evaluation of mineral resources (with special emphasis on constructional materials and ground-water supplies), and the general dissemination of geologic knowledge for educational purposes. The field operations include geologic surveys by the Geologic Branch and ground-water investigations by the Ground Water Division of the Geological Survey.

Routine geologic mapping is being done by quadrangles, using as base maps the new series of quadrangle topographic maps, scale 1/31,680, contour interval 10 feet. It is expected that in general two geologic maps will be prepared for each quadrangle, one to show the distribution of surficial deposits (chiefly glacial) and actual bedrock exposures, and the other to show the distribution and structure of bedrock formations. The compilation of two geologic maps of the State from these quadrangle maps will be started soon and kept up to date as mapping proceeds.

Up to now field work has been completed for 21 quadrangles, and 10 other quadrangles are partly done. Publication has been very slow owing to the War and to lack of funds for publication, but it is expected that maps will appear soon in the proposed new geologic map series of the Geological Survey.

Four shoreline studies relating to shore processes and protection of the coast line have been made, and another is in progress. Three of the reports have been published.

Special studies include a report on the geologic features of the Connecticut Valley as related to recent floods, the geology of the Fresh Pond-Mystic Valley area as related to ground-water supply, and a seismic-geologic study of Governor's Island in connection with construction of the East Boston airport.

Highway studies include reconnaissance mapping of several proposed major highway locations about 25 seismic-geologic studies of deep-cut and bridge locations, and four gravel-sand resources investigations embracing about 12 of the 7½-minute quadrangles. The various highway reports are for engineering use and are not published, but most of them are available for consultation in open files.

During the War period routine quadrangle mapping was temporarily discontinued, and only engineering and mineral-resources studies were carried on. Ten brief reports on mineral areas were made; seven of these are available in open files, and three have been mimeographed for distribution. Regular quadrangle mapping has been resumed since the end of the War.

SIGNIFICANCE OF THE CHELMSFORD, MASSACHUSETTS, GRANITE IN NEW ENGLAND GEOLOGY†

BY L. W. CURRIER

The "Chelmsford granite" in northeastern Massachusetts is a commercial stone quarried extensively in a belt about 15 miles long and up to 2½ miles wide. It is believed to have been formed by metasomatic replacement of beds of the Merrimack quartzite. Original bedding, folds, axial-plane schistosity, and minor faults are preserved. Inclusions of schist and quartzite conform in general attitude to the regional structure, as does also the relict bedding in the granite. The border zones are gradational both across and along the strike, with many thin septa in *lit-par-lit* and digitate pattern.

The process of granitization consisted chiefly of the formation of alkalic feldspars through the introduction of soda and probably some potash. Base elements were displaced. In the metamorphic rocks of eastern New England "granitization" phenomena range from incipient feldspathization in low-grade zones to the formation of granitic gneisses and "replacement granite". It is believed that the process was prominent in regional metamorphism, and the degrees of feldspathization are reflected in a general pattern of metamorphic grade zones. It is suggested that displaced bases may have become fixed in the belts of low-grade metamorphism. The source of hydrothermal solutions,

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however, was probably a general deep-seated magma basin, whence came also local intrusions of granites that do not conform to the general zonal pattern and that also had little metamorphic effect upon the adjacent country rocks. The hypothesis, then, would imply a close relationship between regional metamorphism and deep-seated sialic magma.

BASIC MECHANISMS APPLIED TO CRYSTAL-GROWTH TECHNIQUES

P. H. EGLI AND PAUL L. SMITH

Concepts helpful in growing single crystals can be derived from consideration of Gibbs' equation of surface equilibrium, Kossel's hypothesis of ionic addition, and a rate equation for heterogeneous processes. Factors important to crystal growth which are thus emphasized include supersolubility, superheatability of nuclei, tangential growth, the effects of foreign ions, and the effect of temperature.

Some of the phenomena are more easily demonstrated in growth from melts but have been shown to be equally important in solution. Attention to the basic principles has been useful in guiding growth experiments both from solution and from melts.

Practices helpful to growth which are thus suggested include vigorous preheating of solutions, selection and preparation of seeds and preferred orientation in mounting, control of nucleation and habit by contaminants, the extent to which increased agitation is helpful, and the relation of growth rate to size.

Although far from infallible, the success of the techniques thus developed contributes additional evidence concerning parts of the theory of crystal growth which have not yet been resolved.

GEOLOGY OF THE MONADNOCK AREA, NEW HAMPSHIRE

BY KATHARINE FOWLER-BILLINGS

The Monadnock area includes the Monadnock quadrangle and the northern part of the Winchendon quadrangle as far south as the Massachusetts State Line. The dominant physiographic feature of the region is Mt. Monadnock, which rises 2000 feet above the surrounding lowlands. Structurally, Mt. Monadnock is a broad syncline plunging gently to the northeast, with beds of sillimanite schist and gray quartzite of the Littleton formation of lower Devonian age thrown into many minor folds. More than 50 per cent of the rocks of the area belong to the Littleton formation, which includes highly recrystallized gneissoid types, as well as mica-garnet schists, sillimanite schists, and quartzites. One or more members of rusty, pyritiferous quartzite, interbedded with biotite schists and actinolite schists, are present.

The eastern edge of a large dome of the Oliverian magma series of middle Devonian (?) age appears along the western part of the Monadnock quadrangle. Slightly foliated granites have intruded the Ammonoosuc volcanics of Ordovician age. The Ammonoosuc volcanics are the oldest rocks of the area and are exposed in a narrow belt along the contact of the granites of the Oliverian magma series. An intermittent belt of Clough quartzite of Silurian age overlies the Ammonoosuc volcanics. There are three separate intrusives belonging to the late Devonian (?) New Hampshire magma series. The oldest of these, a dark, slightly foliated granodiorite, is tentatively correlated with the Hardwick granite of Massachusetts. A coarse, porphyritic, foliated rock called the Kinsman quartz monzonite is the next in age. The youngest granite of the New Hampshire magma series is a fine- to medium-grained binary granite called the Concord granite. Pegmatites are associated with all the granite intrusives.

STRATIGRAPHY AND STRUCTURE OF THE MT. PAWTUCKAWAY QUADRANGLE, SOUTHEASTERN NEW HAMPSHIRE

BY JACOB FREEDMAN

The principle of metamorphic zoning applied to the stratigraphy of southeastern New Hampshire in the Mt. Pawtuckaway quadrangle indicates that Katz's interpretation of the stratigraphic relations of the Berwick formation is erroneous. Katz's pre-Algonkian Berwick gneiss is a middle-grade biotite schist which overlies the Paleozoic (?) Eliot formation.

In general the formations strike northeast and dip steeply northwest. Inasmuch as drag folds

indicate that the strata are younger northwestward, southeastern New Hampshire is on the northwest limb of an anticlinorium.

The metamorphic rocks in the Mt. Pawtuckaway quadrangle are assigned to four stratigraphic units: the Eliot, Berwick, and Gonic formations, and a fourth formation to which no name has been assigned. The Eliot formation consisted originally of interbedded calcareous shale and sandstone which have been metamorphosed to quartz-calcite-sericite phyllite and sericite quartzite. The black phyllite member at the top of the Eliot formation was originally a carbonaceous shale. The Berwick formation consisted originally of interbedded sandstone and shale, which were metamorphosed to quartzite and biotite-quartz schist. Local areas of dolomitic limestone in the Berwick formation became narrow layers of diopside-actinolite rock. The Gonic formation consisted originally of shaly sandstone which was metamorphosed to coarse-grained mica schist. The fourth formation consisted originally of shale and shaly sandstone, which were metamorphosed to garnet-staurolite schist and siliceous mica schist. Metamorphism increases in intensity to the northwest.

Plutonic rocks of the Devonian (?) New Hampshire magma series, ranging from diorite to granite, intrude the metamorphic rocks. In the Pawtuckaway Mountains, a small, circular body of Mississippian (?) White Mountain magma series, ranging from gabbro to syenite, was emplaced by cauldron subsidence and ring-dike injection.

Inasmuch as the nearest fossil locality is 30 miles away, the age of the metamorphosed sediments is uncertain. Katz considered them to be Pennsylvanian (?), but they are apparently older than this. Although some of the younger units may be lower Devonian, the older formations are probably early Paleozoic.

WOMEN IN GEOLOGY

BY CAROLINE E. HEMINWAY

Although geology is generally considered a field for men, there are, at the present time, many women who are actively engaged in some phase of geology. This may be shown by an examination of the various membership rolls of the scientific and professional societies. These women have gone into a great variety of commercial positions, into museum work, and into research, as well as into the teaching profession.

In addition to those women who are gainfully employed in geological work, there are many who are keenly interested in geology, who have had an undergraduate major in that subject and, in many cases, some advanced work at a graduate level. The training of these nonprofessional women is of particular importance if we wish to improve the general level of popular knowledge of earth science in the community.

Since these two groups, the professional and the nonprofessional, must be considered, the undergraduate major for women should be broad but not superficial, and in addition to basic courses in the various branches of geology such a major should include at least one advanced course in a specialized field of geology so that some depth as well as breadth will be secured. These disparate courses comprising the undergraduate program should be correlated in the senior year by a synoptic course which might, for example, be based on the complete geologic study of some specific region.

GROWING SINGLE IONIC CRYSTALS FROM WATER SOLUTION

A. N. HOLDEN

Large single crystals of many ionic materials can be satisfactorily grown from water solution in a "reciprocating rotary crystallizer." For one material studied, the observations are consistent with the view that in this apparatus the rate-controlling process is crystallization rather than diffusion. Major problems remaining are the prevention of strained growth, often followed by spontaneous fracture, and a better-informed use of additives as habit modifiers.

VERMONT GEOLOGICAL SURVEY

BY ELBRIDGE C. JACOBS

Vermont was the last of the New England States to establish a geological survey. Agitation for such a survey began in 1835, but it was not until 1844 that an enabling act was passed by the Legis-

lature. Charles B. Adams was appointed State Geologist in 1844; since then nine State geologists have held office although only a few of them have been productive. Outstanding among these were Charles B. Adams (1844–1848), Edward Hitchcock (1856–1864), and George H. Perkins (1898–1933).

Hitchcock's *Geology of Vermont* (two quarto volumes, 988 pages) was the most comprehensive work on the subject ever written and is still useful to discriminating readers. During Perkins' tenure many eminent geologists contributed important papers to his reports.

The office of State geologist has been almost wholly a part-time job, much handicapped by insufficient funds. But recently increased appropriations are enabling the present incumbent to get on with the areal mapping of the State, a task which will require many years to complete.

GROWING OPTICAL CRYSTALS FROM THEIR MOLTEN SALTS

BY H. C. KREMERS

Two general factors must be considered in growing crystals from their molten salts.

(1) *Purity of the Salt*

This may be a very simple process such as in the case of sodium chloride and will become much more complicated in the case of lithium fluoride or calcium fluoride.

(2) *Growing Technique*

a Considerable additional purification must be effected during growing of the crystal. It is more than a simple solidification of the melt into one single crystal.

b In addition to purification during crystal growth optical clarity and homogeneous crystals must be obtained. This is attained by growing crystals such as NaCl, KBr, LiF, $NaNO_3$, etc., under carefully controlled gradients. In atmospheric-type furnaces a wide variation in gradient is possible.

In vacuum-type furnaces used in the growing of CaF_2, LiF, BaF_2, etc., very high gradients are established, and their control is very critical.

c Single-crystal yield is a continuous problem. Seeding is not satisfactory. Initial single-crystal formation is controlled by proper gradients.

CULTURAL VERSUS THE PROFESSIONAL APPROACH TO GEOLOGY FOR COLLEGE STUDENTS

BY RICHARD J. LOUGEE

The distinctions between a technical school and a liberal-arts college extend into the type of scholar each produces. Technical training produces a highly specialized and professionally competent student upon graduation, and liberal-arts training leaves a broadly educated but professionally inept product. Nevertheless many students choose liberal-arts institutions rather than technical schools because they prefer the broader education. The less intense treatment of science in liberal-arts colleges is no reflection on the effectiveness of their approach, for liberal-arts students after receiving graduate training may become as good professionals as those whose undergraduate training in geology was more intensive. Their maturity in preparation may be delayed somewhat, but this is counterbalanced by their command of useful knowledge in other fields.

The great majority of students in geology in the liberal-arts college never intend to become professionals, but as they are in the majority their science requirements commonly set the standard for the geological instruction. Again this need not be decried, for through inspiration received in their casual or chance contact with an introductory geology course many make geology their chosen field, whereas they might have been deterred from taking geology had it been presented with a professional approach.

The writer gives several reasons for his belief that it is neither desirable nor feasible in a liberal-arts college to offer elementary material in the manner of the technical school and he discusses teaching methods which he has found effective in his cultural approach to geologic instruction.

TIME MEASUREMENTS OF POTHOLE DEVELOPMENT AT WESTFIELD, MASSACHUSETTS

BY RICHARD J. LOUGEE

Potholes are a common feature in New Engand river beds, but almost nothing is known about the speed and duration of their development. This can be estimated in the case of an abandoned glacial river gorge 4 miles west of Westfield, and 100 yards south of the Granville Road at a point a quarter of a mile southeast of the West Parish Water Filtering Station (Southwick quadrangle). The gorge,

cut in micaceous gneiss, has several potholes 6 feet in diameter which are breached on one side; the highest reaches at least 40 feet above the now dry floor. If the top of the highest pothole was once the stream bed, the stream intrenched 40 feet in solid rock. Recession of the last ice sheet from the northeast slopes of Drake Mountain permitted the first marginal drainage from the west to flow through this gorge. When the ice front withdrew 1500 feet farther northward the waters were diverted eastward around a hill to a lower series of cascades, and the gorge was abandoned.

Antevs' varved-clay measurements show a rate of ice recession ranging between 116 and 243 feet per year in western Massachusetts; hence the interval between uncovering and abandoning of the gorge must have been somewhere between 6 and 13 years. The prodigious quantity of gravel and cobble lodged below the gorge in the valley of Munn Brook, and reaching a thickness of at least 100 feet, was carried through this gorge in the brief time of its development.

NEW HAMPSHIRE'S GEOLOGICAL STUDIES

BY T. R. MEYERS

Although there has been no formal State Geological Survey in New Hampshire since 1878, most of the functions of such an organization have been provided in recent years through the co-operative efforts of State agencies, the U. S. Geological Survey, and students of geology. Programs and some of their results attained to date include: complete coverage of the State by topographic maps; the completion of a moderately detailed study of the State's surficial deposits, and the beginning of a program of detailed mapping. The detailed mapping of the State's complex bedrock is approximately half completed; the mineral resources of present or potential value are being investigated; and studies of both surface and ground water are in progress.

STRUCTURE AND METAMORPHISM OF THE KEENE-BRATTLEBORO AREA OF NEW HAMPSHIRE AND VERMONT

BY GEORGE E. MOORE

The rocks of the Keene-Brattleboro area of New Hampshire and Vermont include metamorphosed sedimentary and volcanic rocks ranging in age from Ordovician (?) to Devonian, and igneous rocks of probable Devonian age.

The Ordovician (?) Waits River and Orfordville (?) formations occur in north-south-trending belts on the west side of the area and are separated from the other rocks by the Northey Hill fault which has been traced for over 100 miles to the north.

The Ordovician (?) Ammonoosuc volcanics and Partridge formation, the Silurian Clough formation, and the Denovian Littleton formation occur as bands around bodies of granitic gneiss of the Oliverian magma series which form the cores of broad anticlines having a general north-south trend. The members of this magma series were intruded before or during regional deformation.

A large concordant body of Kinsman quartz monzonite of the New Hampshire magma series was intruded into the Littleton formation near the close of the period of orogeny.

Faults are a conspicuous structural feature of the area. In addition to the Northey Hill fault, the eastern Triassic border fault extends northeasterly across the area to the vicinity of Keene, New Hampshire. Numerous normal faults in three separate areas in one of the bodies of gneiss of the Oliverian magma series have formed graben in which parts of the roof rock of the pluton have been preserved.

Most of the rocks west of the Northey Hill fault are in the low-grade zone of metamorphism. The rocks east of this fault are in the middle- and high-grade zones. The intensity of metamorphism, in general, increases toward the east.

IGNEOUS AND METAMORPHIC ROCKS OF NORTHEASTERN RHODE ISLAND*

BY ALONZO QUINN

From oldest to youngest, the rocks of northeastern Rhode Island fall into the following groups: (1) the Blackstone series of metamorphosed sedimentary and igneous rocks, (2) an old group of plutonic rocks, (3) Quincy granite and a related granite porphyry, (4) sedimentary strata of Pennsylvanian age, and (5) scattered "trap" dikes of unknown age.

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Although the relative ages of the above-mentioned large groups of rocks seem well established, the dating is very uncertain, except for the Pennsylvanian rocks of the Narragansett Basin which contain fossils.

The Blackstone series includes greenstone of both intrusive and extrusive origin, quartzite, quartz-mica schist, and marble.

The old plutonic rocks are known to be younger than the Blackstone series because of the discordant relations and the inclusions of the Blackstone series. They are considered to have had a magmatic origin on the basis of structural relations to the Blackstone series.

The Quincy granite and related granite porphyry are also of magmatic origin.

The rocks of the Blackstone series were tilted and affected by a low-grade metamorphism before the Pennsylvanian beds were deposited. There is marked discordance between the northwest-southeast strikes of the Blackstone series and the north-south trends of the Pennsylvanian strata. The old plutonic rocks have also been affected by low-grade metamorphism. Later igneous and sedimentary rocks have not been metamorphosed.

RECENT GEOLOGICAL WORK IN RHODE ISLAND

BY ALONZO QUINN

The Rhode Island Industrial Commission in co-operation with the United States Geological Survey has begun a geological survey of Rhode Island for the purpose of making available to this industrial State basic geological facts. A consideration of the nature of the geological features and of the types of human activity indicates that the most useful information will be the location of bedrock areas; the distribution of sands, gravels, and other structural materials; and the quality, quantity, and depth of ground-water supplies.

The general plan of work is to describe each 7½-minute quadrangle as to bedrock, surficial features, and ground water. Colored geologic maps of the bedrock and of the surficial deposits are planned, as well as such maps as are needed to illustrate ground-water conditions.

Results already published include a bibliography of the geology of Rhode Island and two preliminary reports on the ground water of the Providence area. Reports and maps of the bedrock, the surficial features, and the ground water of the Pawtucket quadrangle are in process of publication. Maps of the bedrock and of the surficial deposits of the Georgiaville quadrangle are near completion.

STRUCTURAL AND ECONOMIC CHARACTERISTICS OF CERTAIN PEGMATITES IN TOPSHAM, MAINE*

VINCENT E. SHAININ

More than 140 pegmatites have been mapped and studied in the vicinity of Topsham, Maine. The pegmatites are enclosed in biotite gneiss, granite gneiss, and aplite. Field evidence indicates that some of the pegmatites formed, in part at least, by replacement of the wall rock and that others were emplaced by forceful injection.

The pegmatites are broadly similar in internal structure. Zones are clearly displayed in some pegmatites—in general those that have been most deeply exposed by erosion or feldspar mining. Five zones occur in the following succession from the walls inward: border zone, graphic granite-quartz-plagioclase wall zone, quartz-muscovite intermediate zone, perthite intermediate zone, and quartz-perthite or quartz zone. The fifth zone appears to form the cores of the pegmatites. The bulk of the feldspar produced has come from the wall zones of the larger pegmatites, and the remainder from the perthite intermediate zones and quartz-perthite cores.

Although fracture-controlled replacement bodies were found in one pegmatite, and hydrothermal fillings have been described from cavities in another, there is no evidence of hydrothermal replacement on a large scale.

PARAGENESIS OF THE CHICKERING PEGMATITE NEAR WALPOLE, N. H.

BY BENJAMIN M. SHAUB

The Chickering pegmatite, relatively small, is located about 3 miles northeast of Walpole, New Hampshire. It was worked for a short time for feldspar and abandoned. The excavation has re-

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yealed a mineral deposit consisting chiefly of perthite, quartz, muscovite, tourmaline, cleavelandite, and some of the less common lithium, magnanese, iron, phosphate minerals.

The pegmatite magma was injected into high-grade schists which show limited reaction or solution due to the presence of the magma. The pegmatite does not show the effect of prominent replacement but rather a progressive crystallization. During the crystallization and cooling of the pegmatite, small cavities developed which now contain carbonates and phosphates.

SYNTHESIS OF QUARTZ CRYSTALS IN GERMANY

BY A. C. SWINNERTON

The production of quartz crystals was undertaken during the last year of the war in Germany following successful experimentation in one of the three programs of synthetic quartz investigation. The successful Nacken method is based on the contrast in solubility of the several forms of silica, particularly that between vitreous silica and low-quartz. Low-temperature fusion techniques and reaction methods did not yield satisfactory results.

FOSSIL RADIOLARIAN BEDS OF SOUTHWESTERN ECUADOR

BY HANS E. THALMANN

Notwithstanding the recent monographs by Clark and Campbell fossil Radiolaria are still one of the neglected fields in micropaleontology. They certainly merit future intensive investigation in order to ascertain their stratigraphic and paleobiologic and ecologic importance and value.

Certain layers of the Eocene section, southwestern Ecuador (Santa Elena Peninsula) often are tremendously rich in these well-preserved minute organisms. In general, two conspicuous forms are encountered: tiny circular cake-shaped discs, with flat edges and without radial appendages, up to 1 millimeter in diameter of the Porodiscidae (*Porodiscus* and its subgenus *Trematodiscus*) of the *P. circularis* Clark and Campbell type, and perfectly globular forms with simple shell pores and distinct lattice structure of the Liosphaeridae (*Cenosphaera* and its subgenus *Circosphaera*) of the C. *veneris* Clark and Campbell type. These spumellarian genera often make up the entire wash residue. Nassellarian representatives occur only sporadically and extremely rarely.

In contrast to the Eocene assemblages, *Staurodicta* and *Stylodicta* prevail in upper Cretaceous sediments of western Ecuador, accompanied occasionally by representatives of the genera *Spongosaturnalis*, *Stylotrochus*, *Spongodiscus*, and *Dictyomitra*.

Eocene occurrences are associated with near-shore, upper Cretaceous with off-shore deposits. Volcanic activity occurred during both times and provided amply the siliceous material for the radiolarian skeletons.

GLOBOTRUNCANA IN UPPER CRETACEOUS SEDIMENTS RECORDED BY EHRENBERG IN 1840

BY HANS E. THALMANN

C. G. Ehrenberg (1795–1876), one of the fathers of micropaleontology, published in a paper dealing with the lithogenesis of chalky rocks and marls by "invisible polythalamous animalcules" (a Phys. Abhandl. k. Akad. Berlin for 1838, Berlin, 1840, Pl. 4) figures of Foraminifera, amongst which a modern micropaleontologist undoubtedly recognizes representatives of the genera *Gümbelina*, *Bolivina*, *Planulina*, *Globigerina*, *Textularia*, and particularly of *Globotruncana*. Ehrenberg gives short descriptions in Latin of the followings species, which, thanks to their characteristic horizontal section, are herewith attributed to the genus *Globotruncana*, namely *Rotalia globulosa*, *R. perforata*, and *R. stigma*, and *Rosalina laevigata* Ehrenberg. Although no vertical sections are given, useful for specific determination, these forms are linked with the *Globotruncana linnei—apenninica—renzi* group of the Upper Cretaceous. Ehrenberg records them from Upper Creataceous sediments of Puszkary near Grodno, Poland; Jutland, Denmark; Gravesend, England; Meudon near Paris, France; Cattolica and Caltanisetta, Sicily; El Qahira and Thebes, Egypt; Hamman Faraun, Sinai Peninsula; Oran, Algeria; and from Greece. These are the first historic records of the important upper Cretaceous index-fossil *Globotruncana*, the first good figure of which was published in 1884 by von Hantken under the name of *Pulvinulina meneghinii*, a true single-keeled *Globotruncana* found as an allochthonous element in a Upper Eocene assemblage, characterized by *Hantkenina kochi* (Hantken) and *Clavulinoides szaboi* (Hantken) at Scarena and Gorbio in the Maritime Alps of Nice, France.

MAINE GEOLOGICAL SURVEY

BY JOSEPH M. TREFETHEN

The first State-sponsored geological work was begun in 1836, with the appointment of Charles T. Jackson as State Geologist. The Jackson survey, lasting for 3 years, was State-wide in coverage. For a 3-year period, 1861–1863, the State survey was revived under C. H. Hitchcock. From the Hitchcock survey to 1930, the State collaborated with the U. S. Geological Survey in the geological mapping of several quadrangles and in the topographic mapping of a considerable area. From 1930 to date, the office of State geologist has been filled, although funds appropriated have varied. In 1944 the State Geological Survey was placed under the Maine Development Commission by legislative act.

During the war the program was largely confined to strategic-mineral work. The present survey program is divided into five parts:

(1) Service, including identification of minerals and rocks, inspection of prospects, water-supply problems, and answering varied geological questions.

(2) Mapping and study of selected areas of economic interest. The 1946 field studies include sillimanite, limestone, and feldspar areas. A co-operative pegmatite project with the U. S. Geological Survey is under way.

(3) Pleistocene studies of economic significance.

(4) Laboratory work on materials collected by the survey. The Maine Geological Survey has a chemical laboratory, operated in collaboration with the University of Maine, and also limited equipment for mineral separations.

(5) Educational work, consisting largely of giving illustrated talks to various groups. Publications include a biennial report and a recently established series of bulletins.

GEOLOGICAL OUTLOOK IN CONNECTICUT

BY EDWARD L. TROXELL

In outlining the work of this Survey, present and future, one should look at our natural resources from the following viewpoint, defining them into the various categories: (1) those already in production, (2) the minerals and rocks that have been, or are about ready to be, commercialized, (3) the products that give promise in the more or less remote future of being of commercial value, (4) other minerals which, definitely doubtful, may, through some method of processing or through discoveries, prove to be of value to the State.

The actual geological work being done in Connecticut is limited, partly because of a relatively small budget and partly because the Geological and Natural History Survey has to do with plants and animals as well. As part of our post-war program we expect to circularize the industries to see which of a considerable list of minerals and rocks may be made useful.

LINEAGE STRUCTURE IN ALKALI HALIDE CRYSTALS

O. F. TUTTLE

X-ray examination of lineage structure in NaCl crystals reveals two distinct types of misorientation. Type I is found only in crystals grown from solution. The lineage units are rectangular in outline when viewed on a growth (100) surface, but when traced back toward the center or seed crystal they are found to be elongated in the direction of growth. When viewed perpendicular to the elongation they show no evidence of the rectangular shape and are usually highly irregular. Type II is found in crystals grown both from solution and from a melt. The misorientation appears to be a slight bending or undulation of the atomic planes with slope breaks between lineage units. The units are irregular with no evidence of a rectangular outline in any crystallographic direction.

In either type of lineage the magnitude of misorientation can be altered by addition of small amounts of impurities to the solution or melt from which the crystals are grown.

SODA-SILICA-WATER SYSTEM IN THE OPTIMUM REGION FOR QUARTZ SYNTHESIS

O. F. TUTTLE AND I. I. FRIEDMAN

The solubility of quartz in the Na_2O-H_2O system from 1% Na_2O to 25% Na_2O has been determined at 200°C and 350°C.

The rate of solution and redeposition of quartz in 5% Na_2O and 10% Na_2O has been determined at 250°, 300° and 350°C.

At temperatures above 250°C and Na_2O concentrations above 2%, the Na_2O-H_2O-SiO_2 system apparently separates into two liquid phases. The composition of the two phases has been determined.

GROWING OF LARGE CRYSTALS OF AMMONIUM DIHYDROGEN PHOSPHATE

A. C. WALKER

Piezoelectric crystals of quartz, Rochelle salt, and ammonium dihydrogen phosphate (ADP) were used extensively in World War II. Quartz is found in nature, but the other two must be grown from aqueous solutions of their salts. A pilot plant for studying methods of growing ADP was set up by the Laboratories in order to assist the Western Electric Co., in establishing a full-scale plant which produced many thousands of ADP bars for underwater sound apparatus during the war. The growing of Rochelle salt as a commercial enterprise prior to 1940, and the enormous demand for both Rochelle salt and ADP during the war, so stimulated the art of crystal culture that it has achieved the status of an important industry within a few years. It is the purpose in this paper to describe some features of ADP crystal culture in the pilot plant stage at the Bell Telephone Laboratories.

SYNTHESIS OF NEPHELINE SINGLE-CRYSTALS

BY EDWARD WASHKEN AND JOSEPH S. LUKESH

One of the qualities, other than electro-mechanical relations, that makes quartz so satisfactory an oscillator element is its chemical and physical durability. Hardness, insolubility, and lack of a pronounced cleavage render quartz an ideal material for precise fabrication. In a search for alternatives for quartz, these properties should be borne in mind. Among the silicates which have these properties and which are otherwise potentially suitable are those of the nepheline group, which includes nepheline, $NaAlSiO_4$, kaliophilite, $KAlSiO_4$, and eucryptite, $LiAlSiO_4$. All three are mutually soluble in each other, and, indeed, the naturally occurring materials are never pure. Nepheline always contains an appreciable amount of potassium.

Since the piezoelectric characteristics of nepheline are not known and since natural material is unsuitable for measurement, it is necessary to synthesize large single crystals before a decision can be made as to its suitability. Many observers have synthesized the material, usually in studying phase equilibria. Until the war, no effort was made to obtain large single crystals. German work, in which crystals up to about three-eights of an inch were produced, formed the basis of the present work. Synthesis is carried out in a melt which is fluid below the nepheline-carnegeite transition. By appropriate adjustment of the composition and the cooling rate, crystals whose maximum dimension is of the order of an inch have been grown.

P. 1259 - 1302 taken out for Index